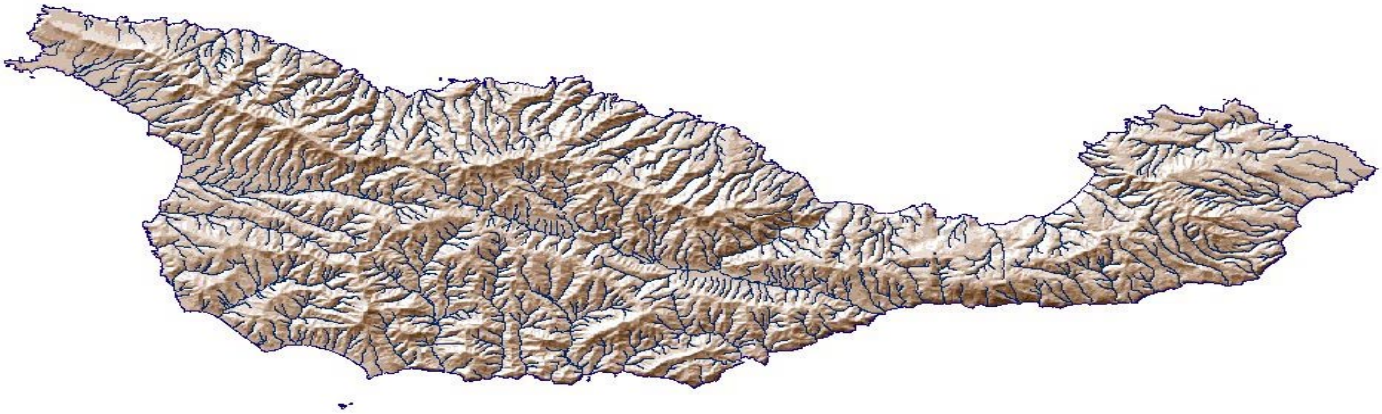
SANTA CRUZ ISLAND PRIMARY RESTORATION PLAN

DRAFT ENVIRONMENTAL IMPACT STATEMENT



Channel Islands National Park

Santa Cruz Island
Santa Barbara County, California

FEBRUARY, 2001

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DRAFT ENVIRONMENTAL IMPACT STATEMENT

Channel Islands National Park

Santa Cruz Island - Santa Barbara County, California

February, 2001

Responsible Official

John Reynolds, Regional Director
Pacific West Region
600 Harrison Street, Suite 600
San Francisco, CA 94107-1372

Lead Agency:

U.S. Department of Interior
National Park Service

For Further Information

Attn: SCPRP
Tim Setnicka, Superintendent
Channel Islands National Park
1901 Spinnaker Dr.
Ventura, CA 93001

Abstract

This Draft Environmental Impact Statement (DEIS) was prepared in accordance with the Department of the Interior National Environmental Policy Act (NEPA) regulations, and the National Park Service (NPS) NEPA guidelines (NPS-12). This DEIS has been prepared because actions proposed as part of this DEIS may be a major federal action significantly affecting the quality of the human environment.

Channel Islands National Park, in coordination with The Nature Conservancy (TNC), has formulated the proposed action to eliminate the ecological degradation that is occurring on Santa Cruz Island from non-native feral pigs. The purpose of the proposed action is to initiate restoration and protection of Santa Cruz Island by eradicating feral pigs and control invasive weeds, such as fennel.

The proposed action will reduce ecosystem and archeological site disturbance and promote species recovery through hunting of feral pigs in fenced units island-wide, as well as reduction of large stands of fennel through controlled, prescribed fire and two successive sprays of herbicide. Using existing and historical fence lines, the island will be divided into six management units of roughly 12,000 acres each. Within these units, feral pigs will be eradicated, clearing one zone before moving to the next. Priority will be given to units that have an increased risk because of native vegetation recovery causing the unit to become unhuntable. Fennel treatment would be focused in areas of higher fennel density that would inhibit pig removal efforts, and will be based upon the successful Central Valley Fennel Removal Project. This protocol consists of burning large, monoculture stands of fennel to reduce standing biomass, followed by spraying with the herbicide Garlon 3A in low mix rates (0.5%-2.0%) for two successive growing seasons to kill resprouts.

For each alternative action, the Park analyzed the potential environmental impacts that would likely occur. Environmental impacts were divided into the following categories: Native Plant Communities, Rare and Listed Plants, Non-native Plants, Native Island Fauna, Non-native Island Fauna, Soil and Water Resources, Cultural Resources, and Human Uses. Under the proposed action, there would be some short-term impacts to native flora, fauna, soils, waters, cultural resources, and human uses due to the activities associated with fennel control and feral pig eradication. However, following fennel control and eradication of feral pigs from a given zone, protection of irreplaceable island resources will be immediate.

This DEIS is open for comment for no less than sixty (60) days, starting on February 23, 2001. Comments should be directed to Superintendent Tim Setnicka at Channel Islands National Park at the above address.

SANTA CRUZ ISLAND PRIMARY RESTORATION PLAN

SUMMARY OF THE DRAFT ENVIRONMENTAL IMPACT STATEMENT

Introduction

Santa Cruz Island, the largest of the Channel Islands off the coast of Southern California, is home to a variety of wildlife including a significant number of plants and animals that can be found nowhere else in the world. Nine of its plants are listed as endangered or threatened under the Endangered Species Act. It is this uniqueness that makes Santa Cruz Island a bastion of biological diversity. An estimated 3,000 archeological sites associated with the Chumash culture are located on Santa Cruz Island. Ninety percent of the island is listed in the National Register of Historic Places (NRHP) for its archeological significance. Channel Islands National Park was established to protect and restore these nationally significant resources.

Non-native, exotic, species introduced to the island throughout the last 200 years have caused extensive damage to the island's rich resources. Without aggressive management actions to reverse the tide of degradation caused by the exotics, the island's rare biological and archeological resources are in peril of being lost forever.

This primary restoration plan proposes actions to 1) eradicate non-native feral pigs, 2) reduce the spread and presence of large populations of non-native vegetation, specifically fennel (*Foeniculum vulgare*), 3) promote the conservation and recovery of rare species of plants and animals and the habitats on which they depend, and 4) eliminate disturbance and degredation of extensive archeological resources.

Description of the Alternatives

The proposed action, Alternative Four, will reduce ecosystem and archeological site disturbance and promote species recovery through annual, phased hunting/trapping of feral pigs in fenced units island-wide. In addition, to accomplish this it will treat large stands of fennel through controlled, prescribed fire and successive treatments with herbicide. Mostly by using

existing and historical fence lines, the island will be divided into six management units of roughly 12,000 acres each. Within these units, feral pigs will be eradicated, clearing one zone before moving to the next. Priority will be given to units that have an increased risk of failure because of native vegetation recovery causing the unit to become unhuntable. Fennel treatment will be focused in areas of high fennel density that would inhibit pig removal efforts, and will be based upon the successful Central Valley Fennel Removal Project, co-funded by The Nature Conservancy and the Mellon Foundation. This protocol consists of burning large, monoculture stands of fennel to reduce standing biomass, followed by treatment with the herbicide Garlon 3A in low mix rates (0.5%-4.0%) for two successive growing seasons to kill resprouts.

Alternative Features	***Alternative One*** ***No Action***	***Alternative Two*** ***Simultaneous Island-Wide Eradication of Pigs***	***Alternative Three*** ***Eradicate Pigs from ESCI/ Exclude Pigs from Selected Sensitive Resources on C/WSCI***	***Alternative Four*** ***Sequential Island-Wide Eradication by Fenced Zone Hunting***
Pig Eradication Strategy	No Eradication Strategy would be implemented	Hunt all areas simultaneously until all pigs are eradicated	Create two pig zones: eradicate pigs in NPS zone; exclude pigs from selected resources on TNC property	Hunt and trap pigs by zone until all pigs are eradicated
Miles of Fence Construction	None	None	~10	~45
Duration of Project	0	2 years of eradication, 5 years inspect and monitor	2 years of eradication, exclude forever	6 years of eradication, 5 years inspect and monitor
Fennel Control	None	Prior to pig eradication - Burn fennel in the fall; aerially spray with herbicide two consecutive springs	Prior to pig eradication - Burn fennel in the fall; aerially spray with herbicide two consecutive springs	Prior to pig eradication - Burn fennel in the fall; aerially spray with herbicide two consecutive springs

Summary of Environmental Impacts

For each alternative action, the Park analyzed the potential environmental impacts that would likely occur. Environmental impacts were divided into the following categories: Native Plant Communities, Rare and Listed Plants, Non-native Plants, Native Island Fauna, Non-native Island Fauna, Soil and Water Resources, Cultural Resources, and Human Uses.

The Proposed Action is Alternative Four: Sequential, Island-wide Eradication by Zone Hunting. Under this alternative there would be some short-term impacts to native flora, fauna, soils, waters, cultural resources, and human uses due to the activities associate with fennel control and feral pig eradication. However, following fennel control and eradication of feral pigs from a given zone, protection of irreplaceable island resources will be immediate.

Native Plant Communities

- *Alternative One* - Fennel will continue to spread, aided by rooting pigs. Pigs will continue impacts on vegetation through rooting, accelerated soil erosion, seed predation, carrying of weed seeds, and creation of trails.
- *Alternative Two* - Fennel burn will increase soil nutrients in the short term, and kill some native plants. Fire will stimulate seed germination of some native plants. Small patches of native plants and boundary areas may experience mortality due to herbicide effects. The control of fennel and eradication of feral pigs will have substantial positive effects on native plant communities.
- *Alternative Three* - Effects from fennel burn and herbicide application same as Alternative Two. The control of fennel and eradication of feral pigs will have substantial and positive effects on native plant communities on approximately 24% of the island. Most of the island's native plant communities will be exposed to the feral pig impacts described in Alternative One.
- *Alternative Four* - The environmental consequences are substantially similar to Alternative Two. The primary difference is that the project will take approximately 4 years longer to complete and there will be impacts from fence building and removal. Effects from fennel burn and herbicide application same as Alternative Two. The control of fennel and eradication of feral pigs will have substantial and positive effects on native plant communities.

Rare and Listed Plants

- *Alternative One:* Feral pigs will continue to impact almost all known populations of listed plant species.
- *Alternative Two:* One listed plant species, *Galium buxifolium*, occurs on the isthmus where the dense fennel occurs. However, the *Galium* does not co-occur with the fennel. No burning or herbicide is planned for the coastal bluff habitat inhabitated by the *Galium* and no effect is anticipated. The nine listed plant species and numerous rare plants should all benefit from the eradication of feral pigs.

- *Alternative Three:* Some protection will be afforded to rare and listed plant species due to fencing existing populations. However, sustained protection will be difficult due to the ability of pigs to break through fencing over time. Populations will not be able to recover to new habitats because of the continued presence of feral pigs.
- *Alternative Four:* Same as Alternative Two except that it will take approximately 4 more years to achieve the feral pig eradication and protect all of the rare and listed plants.

Non-native Plants

- *Alternative One:* Non-native plants will continue to benefit from the ground disturbance activities of feral pigs. Fennel will continue to expand into native plant communities and establish dominance.
- *Alternative Two:* Fennel burn may enhance Mediterranean annual grasses. Fennel will be greatly decreased. Herbicide application will greatly reduce fennel and should reduce other non-native dicots. Removal of pig disturbance will substantially reduce long-term establishment and spread of non-native plants.
- *Alternative Three:* Environmental consequences will be similar to Alternative One: No Action for the central and western portions of the island. To the extent that pigs can be excluded from the eastern 24% of the island, the environmental consequences there will be similar to Alternative Two.
- *Alternative Four:* Same as Alternative Two. Fence building and removal will likely create some bare ground and may increase weed spread into disturbed areas near fencelines.

Native Island Fauna

- *Alternative One:* Pigs will continue to directly and indirectly impact native wildlife through destruction of habitat, predation, competition for food, supporting enhanced populations of predators (such as ravens). Island Foxes will face continued predation from non-native golden eagles.
- *Alternative Two:* There will be short-term effects on small animals due to the fennel burn. Elimination of dense fennel stands will cause changes in species composition in the long-term. Herbicide treatment is not expected to affect island fauna. Feral pig eradication will remove direct competition and predation on many island animal species. Island foxes would not face predation from non-native golden eagles nor competition for food.
- *Alternative Three:* Same as Alternative One: No Action for Island Foxes. Native wildlife, such as mice, lizards, and snakes on the eastern portion of the island will benefit (similar to Alternative Two) from the eradication of feral pigs in that area.
- *Alternative Four:* Same as Alternative Two, although approximately 4 more years will be needed to eradicate the feral pigs.

Non-native Island Fauna

- *Alternative One:* Without eradicating pigs, pigs would remain abundant on the island. This readily available food source would be adequate to support the continued nesting by non-native golden eagles. The golden eagles would continue to opportunistically prey on native island endemic species such as the island fox and the island spotted skunk.
- *Alternative Two:* Removal of pigs will eliminate the primary prey base for golden eagles. Golden eagles would no longer be able to sustain resident populations on the island.
- *Alternative Three:* Effects from fennel burn and herbicide application same as Alternative Two.
- *Alternative Four:* Same as Alternative Two, although approximately 4 more years will be needed to eradicate the feral pigs.

Soil and Water

- *Alternative One:* Pig rooting and herbivory will continue to reduce plant cover and greatly increase soil erosion and sedimentation of streams.
- *Alternative Two:* Fennel burn and herbicide will reduce ground cover and could lead to increased erosion and stream sedimentation in the short-term. Eradication of feral pigs will greatly reduce soil disturbance, destruction of cryptobiotic crusts, and lessen soil erosion and stream sedimentation. Soil nutrient levels will increase in the short-term from the fennel burn.
- *Alternative Three:* To the extent the NPS is successful keeping pigs from reinvading the eastern portion of the island, the environmental consequences in this area will be the same as Alternative Two. However, for the remainder of the island (with the exception of selected fenced areas) the environmental consequences will be the same as Alternative One: No Action.
- *Alternative Four:* Same as Alternative Two, although approximately 4 more years will be needed to eradicate the feral pigs.

Cultural Resources

- *Alternative One:* Pigs will continue to destroy irreplaceable archeological sites and will degrade the scientific values of the Santa Cruz Island Archeological District.
- *Alternative Two:* The fennel burn could affect historical resources, such as fencelines. Fire lines in fennel could cause ground disturbance. The primary impactor of archeological sites, feral pigs, would be eliminated in approximately two years.
- *Alternative Three:* Most of the Santa Cruz Island Archeological District will continue to be impacted by feral pigs. To the extent that pigs are excluded from the eastern portion of the island and fenced out of selected sites on the remainder of the island, archeological sites in those areas will be protected.

- *Alternative Four:* Same as Alternative Two, although approximately 4 more years will be needed to eradicate the feral pigs.

Human uses

- *Alternative One:* Human uses will be largely unchanged. The aesthetics of visits to Santa Cruz Island will be lessened due to the reduction of native wildlife, reduction of plant cover, and destruction of archeological sites. The scientific value of the island will decrease. Pigs may occasionally be dangerous to people in certain situations.
- *Alternative Two:* Elimination of dense stands of fennel will improve the attractiveness of the isthmus for visitor use. Visitor use and access may be limited while hunting of feral pigs is active in selected areas. Elimination of pigs will improve island aesthetics, scientific values, and recreational opportunities.
- *Alternative Three:* Environmental effects will be similar to Alternative Two for most recreational uses. The scientific value of most of the island will decrease. Pigs may occasionally be dangerous to people in the central and western portions of the island.
- *Alternative Four:* Same as Alternative Two, although approximately 4 more years will be needed to eradicate the feral pigs.

Likelihood of Success

- *Alternative One*: The Park also evaluated the "Likelihood of Success" of each of the alternatives. Alternative One No Action makes it impossible for the NPS to achieve its goals for conserving natural and cultural resources on Santa Cruz Island and restoring the natural ecosystems of the island. The facts that nine plant species from Santa Cruz Island have been listed as threatened or endangered and that island foxes have declined precipitously in recent years are indications of the destruction of native resources caused by feral pigs. Numerous archeological sites have been irreversibly damaged by feral pigs.
- *Alternative Two:* This is an excellent strategy for protecting island resources but would be very difficult to achieve because of the need to fund and support a very large operation over a short period of time. Funding realities substantially lessen the "Likelihood of Success" for this alternative.
- *Alternative Three*: This has a low "Likelihood of Success" because more than three-fpourths of the island, containing extremely significant natural and cultural resources, would continue to be subjected to feral pig impacts. Additionally, it is expected that maintaining a pig-proof fence across the island will be expensive and an exercise in futility. Pigs are very adept at breaking through fences. It is doubtful that park personnel, with all the demands and issues they face, could sustain in perpetuity the effort necessary to hold a fenceline. Once pigs breached the fence, even accomplishments on the eastern fourth would be lost.
- *Alternative Four* : This has the highest "Likelihood of Success" because it achieves the best balance of expeditiously and comprehensively protecting resources in a manner that the NPS is likely to be able to support financially and logistically. The longer time necessary to

complete the project will allow more post-sheep vegetation recovery, increasing the difficulty of feral pig eradication and slightly reducing the "Likelihood of Success".

Glossary of Terms and Abbreviations

APHIS	Animal and Plant Health Inspection Service
CDFG	California Department of Fish and Game
CHIS	Channel Islands National Park
C/WSCI	Central and West Santa Cruz Island; TNC owned
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ESA	Endangered Species Act
ESCI	East Santa Cruz Island and Isthmus; NPS owned
Feral	Having escaped domestication and become wild
GMP	Channel Islands National Park General Management Plan
NEPA	National Environmental Policy Act
NPS	National Park Service
NRHP	National Register of Historic Places
RMP	Channel Islands National Park - Resources Management Plan
SCI	Santa Cruz Island
TNC	The Nature Conservancy
USFWS	US Fish and Wildlife Service

SANTA CRUZ ISLAND PRIMARY RESTORATION PLAN

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Santa Cruz Island Primary Restoration Plan

CHAPTER ONE
PURPOSE AND NEED

Introduction

The National Park Service (NPS) and The Nature Conservancy (TNC) have long considered the most critical management actions needed to achieve primary restoration of Santa Cruz Island to be: a) eradicate feral sheep, b) eradicate feral pigs, and c) control fennel. Feral sheep were eradicated from TNC property during 1984-87. The National Park Service concluded an intensive 3-year effort to remove sheep from Santa Cruz Island. This effort has successfully removed approximately 9,270 sheep from the island. At publishing time of this document it is believed that Santa Cruz Island is sheep-free, however, vigilant monitoring for remaining sheep is on-going. Substantial and unaided recovery of native vegetation communities occurred following removal of sheep from TNC property. However, many native habitats and species continue to be severely impacted by feral pigs, fennel, and other non-native plant species.

The presence of feral pigs greatly facilitates the spread of fennel and other invasive weeds. Pig rooting causes massive destruction of native species and leaves bare ground that can be easily colonized by weeds. The removal of non-native pigs will greatly reduce the spread of non-native plants and result in substantial natural recovery of native island resources.

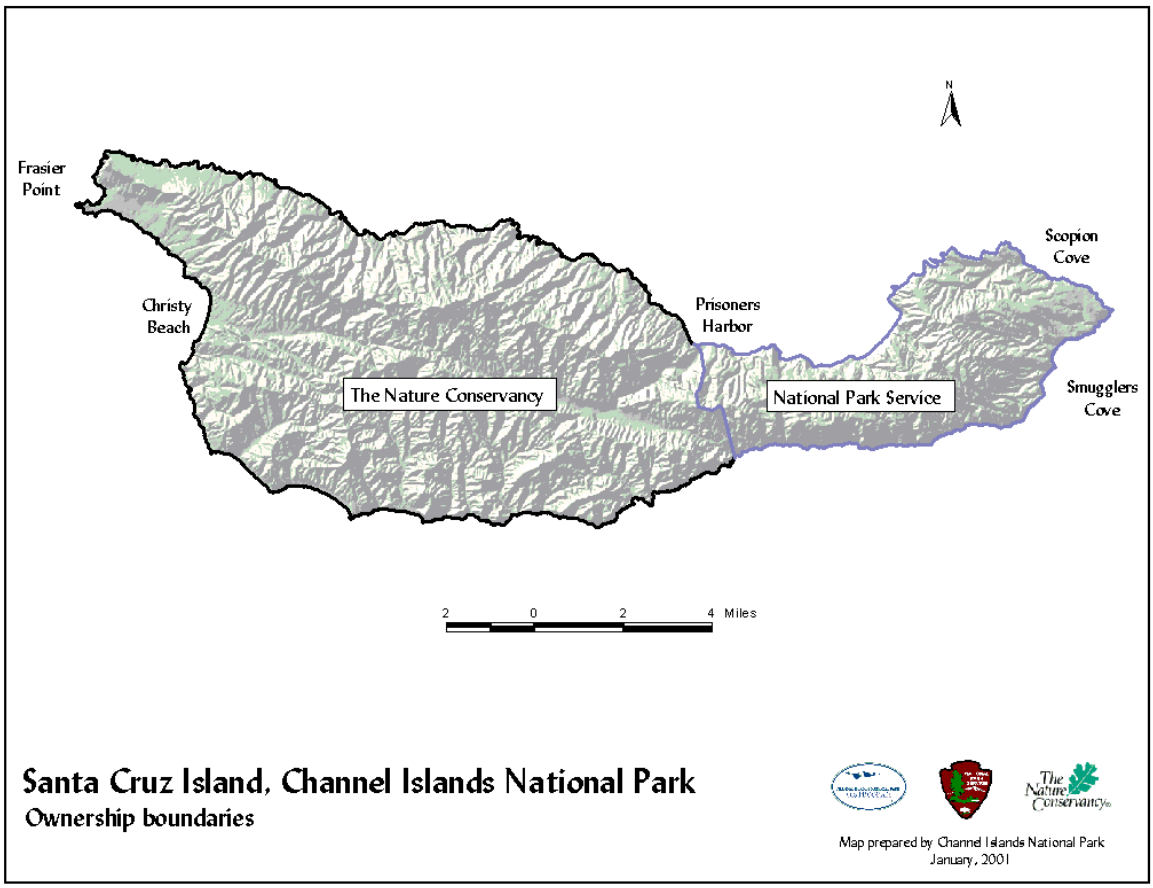
Ownership

The ownership of Santa Cruz Island is divided between the NPS and TNC. NPS owns the eastern 24% of the island (ESCI); TNC owns the western 76% of the island (C/WSCI). (Figure 1).

All of Santa Cruz Island is within the boundaries of Channel Islands National Park (Figure 2). The Park's enabling legislation recognizes the value and appropriateness of achieving park goals through projects anywhere on the island and authorizes the use of federal funds on privately held portions of the park in order to protect and restore valuable resources.

The NPS and TNC share similar mandates for the conservation and protection of natural resources. The mission of Channel Islands National Park is to protect the nationally significant natural, cultural, scientific, and scenic values of the Channel Islands and adjacent marine waters and to provide present and future generations appropriate opportunities to experience and understand park resources. The Nature Conservancy, a private non-profit

Figure 1: Santa Cruz Island Ownership Boundaries



conservation organization, is committed to preserving sustainable ecosystems that maintain and enhance native biological diversity (The California Nature Conservancy 1997).

Guidance for Resource Management

The 1916 NPS Organic Act, (16 USC 1 et seq.) directed that NPS lands be managed to conserve the resources contained within "in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." The Redwoods Act of 1978 (16 USC 1a-1) reaffirmed this principle. In general, these two statutes confer upon the Secretary of the Interior the discretion to determine how best to protect and preserve park resources.

Since the establishment of Yellowstone National Park in 1872 and the subsequent formation of the National Park Service in 1916, the philosophy of natural resources management has evolved. Simple concepts such as protection of wildlife from poaching gradually gave way to recognition of the complexities of comprehensive ecosystem management in a regional and global context (NPCA 1989).

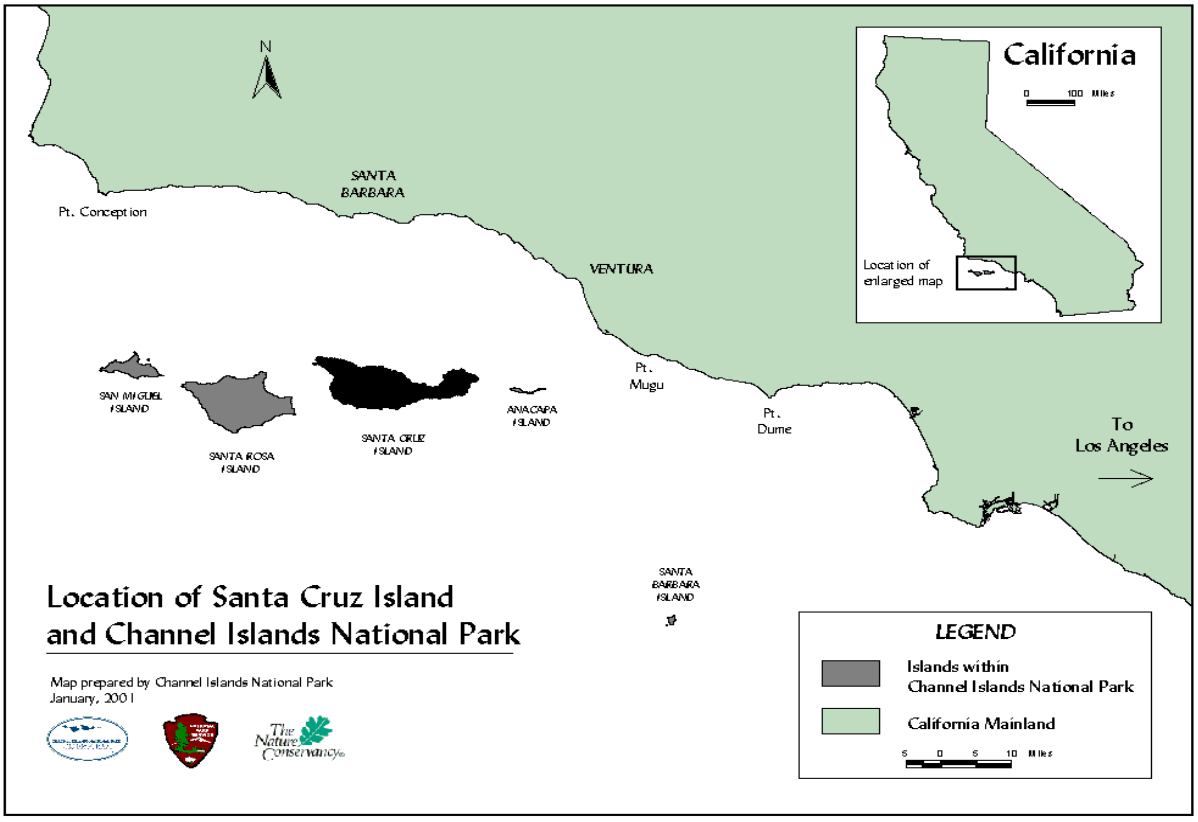
In 1961, the Secretary of the Interior convened a blue-ribbon panel to evaluate how NPS should manage large mammals and other animals. The resultant report (Leopold et al. 1963) clearly directed NPS toward *ecosystem management*, which is the management of all components of an ecosystem as a whole, rather than single species management. The Leopold

Commission promoted the notion that national parks should be managed as "vignettes of primitive America" in order to preserve, to the extent possible, the biota that existed or would have evolved had European humans not colonized North America. Although this has been interpreted by some as a call for "hands-off" management of a static primitive condition or scene, the Leopold Commission actually promoted an aggressive stewardship of parklands with "hands-on" management techniques, and perpetuation of dynamic, evolving ecosystems. For example, the report called for restoration of natural fire regimes in parks.

More recent work has built upon the findings of the Leopold Commission regarding resources management in NPS parks. Parsons et al (1986) states that the principal aim of National Park Service resource management in natural areas is the unimpeded interaction of native ecosystem processes and structural elements. Parks should protect not only structural elements such as plants, animals, soil, water, and air, but also dynamic ecosystem processes such as natural fire, biotic evolution, and nutrient cycling.

In 1989, NPS again convened a blue-ribbon panel to assess the role of resource management and research in the future of national parks. The resulting report (NPCA 1989) validated findings of the Leopold Commission, affirming that the focus of park management should be to maintain or restore native biota and ecosystems and to resist establishment of alien, non-native organisms. Where possible, ecosystem management should attempt to preserve natural processes operating at a scale consistent with the evolution of the ecosystem being managed. The report recommended that NPS move well beyond static scene management to provide stewardship for the elements and processes

Figure 2: Vicinity Map Santa Cruz Island



contained in parks.

National Park Service management policies (NPS 1988) also reflect the development of ecosystem management concepts. In part, the policies state that natural resources should be managed with a concern for fundamental ecological processes as well as for individual species and features:

Managers and resource specialists will not attempt solely to preserve individual species (except threatened or endangered species) or individual natural processes; rather they will try to maintain all the components and processes of naturally evolving park ecosystems, including the natural abundance, diversity and ecological integrity of the plants and animals (NPS 1988).

Guidelines for management of species federally listed as threatened, endangered or candidates for listing are found in NPS management policies and natural resources management guidelines. National Park Service management policies (NPS 1988) and guidelines for natural resources management (1991) establish the affirmative responsibility of NPS, and the individual park, for managing both listed and candidate species. They also stress that management actions should emphasize removal of threats, but also include active recovery efforts, and that management should be done in an ecosystem context.

The Channel Islands National Park General Management Plan (1985) identified the need to remove exotic animals from Santa Cruz Island.

The Endangered Species Act requires that actions authorized, funded, or carried out by Federal agencies not jeopardize the continued existence of listed species. Under section 7(a)(2) of the ESA (16 USC section 1536), federal agencies are required to consult with the U.S. Fish and Wildlife Service (USFWS) on actions which may affect listed species or critical habitat. Because this primary restoration plan proposes actions that could affect the 9 federally listed plant species on Santa Cruz Island, NPS will confer with USFWS on likely effects to those species.

National Park Service management also seeks to preserve and foster appreciation of cultural resources in NPS' custody through appropriate programs of research, treatment, protection, and interpretation (NPS 1988). Guidance for cultural resources management in NPS units is found in National Park Service Management Policies (1988) and Cultural Resource Management Guidelines (NPS-28). Management of cultural resources in NPS units is subject to the provisions of the National Historic Preservation Act (16 USC 470 et seq.), the National Environmental Policy Act (42 USC 4371 et seq.), the American Indian Religious Freedom Act (42 USC 1996), the Advisory Council on Historic Preservation's regulation regarding "Protection of Historic Properties" (36 CFR 800), the Secretary of the Interior's "Standards and Guidelines for Archeology and Historic Preservation (FR 48:44716-40) and "Federal Agency Responsibilities under Section 110 of the National Historic Preservation Act" (FR 53:4727-46).

Purpose and Need

Purpose

The purpose of the Santa Cruz Island Primary Restoration Plan is to protect the unique natural and cultural resources of the island from continued degradation and to initiate recovery of the island ecosystem by:

Eradicating feral pigs island-wide

Controlling fennel

Need for Action

These actions are necessary in order to:

Protect and initiate restoration of native plant communities

Protect rare plant species

Control and reduce the spread of invasive, non-native weeds, such as fennel, *Foeniculum vulgar*e.

Protect island foxes through removal of the non-native food source (feral pigs) supporting non-native golden eagles

Conserve archeological sites threatened by accelerated erosion and pig rooting

Initiate conservation and restoration of soil resources

Invasions by non-native plant and animal species are generally considered to be one of the greatest threats to global biological diversity (Shafer 1990, Soule 1990). These invasions have been described as a "biological wildfire" (Federal Interagency Committee for the Management of Noxious and Exotic Weeds, 1998). Many examples exist demonstrating the negative impacts of non-native animals and plants on native biota. At the population level, native species can undergo a reduction in recruitment, distribution and abundance (Vitousek 1990), or be driven to extinction (Savidge 1987). At the community level, invasions can radically alter the structure and composition of native plant and animal communities (MacDonald and Frame 1988), and at the ecosystem level they can alter nutrient cycles, fire regimes, and other processes (D'Antonio and Vitousek 1992, Singer et al. 1984).

Ranchers and previous landowners of Santa Cruz Island have tried unsuccessfully to eradicate pigs since their introduction almost 150 years ago. Marla Daley, an expert on Santa Cruz Island history, reported (1999) that multiple efforts to eradicate feral pigs have been undertaken by previous landowners using such varied methods as roping, spearing, and the release of the disease - hog cholera. In addition, island scientists have unanimously called for the eradication of feral pigs at the earliest possible date (Brumbaugh 1980, Van Vuren 1981a, Van Vuren 1981b, Hochberg et al. 1980, Baber 1982, Laughrin 1982, Collins 1987, Arnold 1999, Glassow 1999) due to documented impacts to natural and cultural resources. Institutions, agencies, and individuals with long-term associations with Santa Cruz Island have indicated their support for the need of a feral pig eradication program (Coblentz 1988, Ehorn 1988, Laughrin 1988, Power 1988, Van Vuren 1988, Young 1988).

Restoration of native plant communities

The Channel Islands of California are vivid examples of the pervasive impacts that non-native species can have on ecosystems. The most severe impacts to the island chain have been due to exotic animals, especially cattle, feral sheep, goats, and pigs (Brumbaugh et al. 1980, Minnich 1980). In addition to the impacts from feral and domestic livestock, many species of non-native plants have become established and dominate most of the island chain's vegetation communities. Non-native plants now comprise between 20-48% of the species on the islands, and between 25-80% of the ground cover (Halvorson 1992, Junak et al. 1994, and Klinger in prep).

Protection of listed plant species

In 1997 the U.S. Fish and Wildlife Service (UFWS) listed nine plant species on Santa Cruz Island as threatened or endangered. Rooting and grazing by feral pigs was a factor in the decline of each of these species. The Recovery Plan for Thirteen Plant Taxa from the Northern Channel

Islands (UFWS 2000) recommends development and implementation of an …

> … island-wide pig removal plan to prevent the continuing habitat degradation on Santa Cruz Island. The National Park Service should collaborate with The Nature Conservancy and other California Island managers to develop methods that will expedite the elimination of pigs from all of Santa Cruz Island.

Countless resource scientists, including a group of 20 land management professionals convened on SCI in 1998, have made similar recommendations.

Reduce spread of non-native weeds

The spread of many non-native weed species, such as fennel, is greatly facilitated by the transport of their seeds by animals and the presence of bare, unvegetated ground. Feral pigs spread non-native weeds through two basic mechanisms. Pigs feed on the seed heads of annual exotic grasses, fennel, and other weeds. The seeds emerge from the pig's digestive system intact and able to sprout. Pigs also carry seeds in their coats, having the ability to transport seeds many miles from the source point. Further, the rooting of pigs removes vegetative cover and creates bare ground for establishment of weedy plants.

Protection of the Island Fox

The island fox (*Urocyon littoralis*) is endemic to the California Channel Islands. The fox exists as a different subspecies on each of the six islands (Wayne et al. 1991, Collins 1993). It is distributed as six island populations each varying in size from less than a hundred to a few thousand individuals. Due in part to its limited distribution and small numbers, the island fox has been listed as a threatened species in California (California Department of Fish and Game 1987) and is being considered for listing as a federally threatened or endangered species.

The island fox population on San Miguel has declined sharply from levels in 1993 (Coonan et al. 1998) with the adult population falling from 450 in 1994 to 15 in 1999 (Coonan et al., in prep). Monitoring data from Santa Cruz Island and survey data from Santa Rosa Island indicate that island foxes are undergoing similar catastrophic declines on those islands as well.

The catastrophic decline of island foxes appears to be due to predation by non-native golden eagles (Roemer et al. in prep.). The primary year-round food source that sustains the golden eagles is the piglets on Santa Cruz Island. The park is currently attempting to live capture and remove golden eagles from the northern islands. However, until the food source provided by piglets is removed, golden eagles will continuously re-establish populations on the island and prey on island foxes.

Protection of archeological sites

Santa Cruz Island contains a rich archeological record of the Chumash culture contained in some 3,000 sites, with the earliest dating nearly 9,000 years ago. Sites range from isolated artifacts to huge, stratified sites spanning a period of 8,000-9,000 years. The large number, diversity and relatively undisturbed nature of the island sites provide excellent research opportunities for archeological investigations into human adaptation in a context of changing environments and cultural conditions. Ninety percent of the island is listed in the National Register of Historic Places for its archeological significance. The remaining ten percent of the

island is eligible for listing in an expanded archeological district.

Feral pig rooting has damaged a large number of the island sites. Pig rooting to a depth of three feet has been noted in a number of sites. The information potential of some shallow sites and surface scatters has been completely destroyed by pig rooting. Rooting in the upper layers of deeper, more complex, stratified sites profoundly disturbs time and spatial relationships and destroys the context of the information contained in these sites. In addition, pig rooting has disturbed prehistoric and historic period burials found in many locations on the island. Continued pig rooting of archeological sites on the island will result in their loss of integrity, and ultimately loss of the values which make the Santa Cruz Island archeological district eligible for inclusion in the National Register of Historic Places.

Conservation of soils

The long history of grazing by non-native ungulates has greatly accelerated erosion of soils on Santa Cruz Island. Large areas have been denuded of vegetation and are eroded down to bedrock. Rooting by pigs exposes substantial sections of land to erosion by water and wind. Erosion and rooting cause disturbance to archeological sites that have long been protected by vegetation (Glassow and Arnold, pers. comm. 1999).

Scope of the Proposed Action

This document focuses on the concrete and immediate steps that must be taken to reverse the environmental degradation of Santa Cruz Island. The scope of the proposed action is to fully eradicate feral pigs from SCI and to implement significant fennel control measures. These two actions have been determined to be the two most important actions that can be implemented in order to abate on-going resource degradation and recover unique island resources.

The restoration actions proposed in this document will require a major commitment of resources. It is recognized that additional intervention will be required in the future to ensure the full protection and recovery of island resources.

There are many management issues that are outside of the scope of this document. These issues will be dealt with in other plans:

- Long-term visitor facilities and opportunities
- Recovery of listed or rare plant species
- Use of fire as a restoration tool
- Recovery of island fox
- Changes to island infrastructure
- Bald Eagle Reintroduction

Decisions to be Made

For this DEIS, the official responsible for choosing the management action is the National Park Service Regional Director, Pacific West Region. The Regional Director, once the Final EIS has been completed, can decide to:

Select one of the alternatives analyzed within the Final EIS, including the No-Action alternative; or,

Modify an alternative (for example, combine parts of different alternatives), as long as the environmental consequences of the modified action have been analyzed within the Final EIS.

Factors the Regional Director will take into consideration in making a decision are:

- Does the alternative meet National Park Service guidelines and policies, including the Channel Islands General Management Plan?
- How well does the alternative meet the "Purpose and Need" for this project?
- How does the alternative respond to and/or resolve the environmental issues raised for this project?
- The nature and extent of public comment to the DEIS

Santa Cruz Island Primary Restoration Plan

CHAPTER TWO

ALTERNATIVES

Introduction

This chapter describes the four alternatives to be considered for implementation and identifies the significant environmental issues used to formulate these alternatives. The environmental issues were developed as a result of extensive "scoping" conducted for this analysis. The "scoping" actions that were conducted for this analysis are described in detail in Chapter Five "Consultation and Coordination". This Chapter concludes with a section that explains the rationale for dismissing other methods or alternatives from consideration, and a comparison of alternatives.

Alternative Development Process

Section 102(e) of NEPA states that all Federal agencies shall "study, develop, and describe appropriate alternatives to recommend courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources". In addition to responding to unresolved conflicts, an EIS must "rigorously explore and objectively evaluate all reasonable alternatives" [40CFR 1502.14(a)].

Taken together, these requirements determine the range of alternatives and provide the basis for the Deciding Official's informed decision, as required under NEPA. The Proposed Action, described in Chapter 1, was the result of a resource analysis done by NPS and TNC resource management staff in collaboration with pig and fennel control experts. This collaborative effort identified management actions necessary to respond to feral pig and non-native fennel impacts to the Santa Cruz Island ecosystem.

The alternatives detailed below were developed to focus on the issues identified by resource specialists within the NPS and TNC, pig and fennel control experts, university/academic experts, government regulatory agencies, and the general public. Chapter Five – Consultation and Coordination lists all individuals, agencies and organizations that provided substantive input regarding the proposed action.

Internal Scoping and Public Involvement Process

The NEPA "scoping" process [40CFR 1501.7] was used to determine the scope of the analysis and to identify potential issues and opportunities related to the Proposed Action. A complete summary of the scoping and public

involvement process for the proposed project is summarized in Chapter Five.

Significant Environmental Issues

Through the Scoping and Public Involvement Process some significant environmental issues were identified. Significant issues are those that may require project-specific alternatives, mitigation measures or design elements to address the potential effects of the proposed activities.

For clarification, a summary statement that defines the scope of the issue for this project will accompany the identified issues. In addition, for each issue, measurement indices are given to provide a preview of how the issue will be evaluated for direct, indirect, and cumulative effects for each alternative. The "Issue" categories are as follows:

- **Issue 1: Likelihood of Success**
- **Issue 2: Impacts to Vegetation, including Weeds and Threatened and Endangered Plant Species**
- **Issue 3: Impacts to Island Fauna**
- **Issue 4: Impacts to Physical Resources including Soils, Water and Air Quality**
- **Issue 5: Impacts to Social Factors including Cultural Resources and Human Use**

Issue 1: Likelihood of Success

Efficacy for this analysis is defined as how well the alternative would meet the purpose and need; i.e., how well the alternative would protect the unique natural and cultural resources of Santa Cruz Island by eradicating feral pigs and controlling fennel.

Measurement Index

- Likelihood of achieving Island-wide eradication of feral pigs

Issue 2: Impacts to Vegetation, including Weeds and Threatened and Endangered Plant Species

Limited impacts to vegetation would occur as a result of implementing the proposed activities. However, in the long-term, native vegetation will benefit from the eradication of feral pigs and control of fennel. The effects analysis will identify the short-term impacts as well as the expected long-term benefits of implementing the proposed activities.

Measurement Indices

- Health of Threatened and Endangered Species
- Extent of Fennel
- Extent of Other Weed Species

Issue 3: Impacts to Island Fauna

Introduction of non-native flora and fauna to the Channel Islands has disrupted the ecology on all islands. The largest perturbations to Santa Cruz Island have been the introduction of sheep, pigs, and the highly invasive fennel. Sheep are no longer present on Santa Cruz Island, however abatement of feral pigs and invasive weeds would greatly affect island fauna in a beneficial way. The environmental effects section will focus on the following Santa Cruz Island fauna:

Measurement Indices

- Health of Native Island Fauna
- Non-Native Pigs

Issue 4: Impacts to Physical Resources including Soils, Water and Air Quality

Livestock grazing for 150 years on Santa Cruz Island has affected soil resources and water quality. The effects analysis will focus on watersheds of Santa Cruz Island and how loss of vegetation cover, direct soil disturbance, and vegetation type conversion, all impact runoff, soil erosion, and stream degradation/aggradation.

The prescribed fennel burn would create smoke which could result in haze and other contaminants being disseminated into the air.

Measurement Indices

- Soil Disturbance and Erosion
- Watershed level impacts
- Landtype and geomorphology (Water Quality)
- Smoke impacts (Air Quality)

Issue 5: Socioeconomic Impacts including Cultural Resources and Visitor Uses

Cultural resources are non-renewable resources. As such, federal regulations have been passed which prohibit the destruction of significant cultural sites. Significant cultural properties do exist on Santa Cruz Island. The effects analysis will focus on how implementation of each alternative may affect cultural resources on the island.

Visitor use of Santa Cruz Island is different depending on the landowner. Visitor use is accommodated on National Park Service owned lands and is restricted on TNC owned lands. Access by visitors, TNC personnel, Park Staff, and researchers may be restricted or altered in certain areas during implementation activities.

Measurement Indices

- Prehistoric Cultural Resources
- Historic Cultural Resources
- Human Uses

Mandatory Topics and Dismissal of Issues

As required under NPS Directors Order 12, this analysis must address twelve mandatory topics. Listed below are topics that must be addressed followed by a discussion on whether they are relevant to the analysis.

a) Conflict with land use plans, policies or controls – The Park's General Management Plan, as well as the Park's Resources Management Plan identified the need to remove pigs from the Santa Cruz Island. The proposed action does not conflict with local, state, or tribal policies or regulations.

b) Energy requirements and conservation potential – Santa Cruz Island like all of the Northern Channel Islands do not have electric or gas utilities supplied to them. The Park's administration of these islands always emphasizes energy conservation. For instance all housing on the island are totally self sufficient for electricity through the use of solar energy. Significant energy demands may be necessary to transport people, equipment, and supplies to support the operation. Transportation occurs mainly by boats provided by the Park.

c) Natural or depletable resource requirements and conservation potential – Resource requirements for undertaking this project would be to primarily supply the operation. Waste of resources is not an issue with operations that occur on the island. The expense of re-supplying a remote island ensures conservation of available resources.

d) Urban quality, historic and cultural resources – Impacts to these resources can be found in Chapter Four - Impacts to Human Uses.

e) Socially or economically disadvantaged populations – This proposed project would not change the local population's work, recreation, or social interactions. As such

Executive Order 12898 (environmental justice) does not apply to this analysis.

f) Wetlands and floodplains – No development will be occurring in wetlands or floodplains as part of this analysis.

g) Prime or unique agricultural lands – Santa Cruz Island since the early 1800's has been used for rangeland for domestic livestock. Current ownership emphasizes land use conservation over agricultural use. Since no current agriculture practices are occurring on the island no impacts would occur to agricultural lands.

h) Endangered and threatened plants and animals – All plant and animal species listed under the Endangered Species Act as threatened or endangered that occur on Santa Cruz Island have been evaluated for impacts (See Chapter Four).

i) Important scientific, archaeological, and other cultural resources, including historic properties listed or eligible for the National Register of Historic Places – Impacts to cultural resources, including an assessment of impacts to properties listed or eligible for the NRHP have been evaluated in Chapter Four – Cultural Resources.

j) Ecologically critical areas, Wild and Scenic Rivers, or other unique natural resources – Although Santa Cruz Island has many unique natural resources, no resources have status as an ecologically critical area, nor are there any Wild and Scenic Rivers on the island. Impacts to unique natural resources can be found throughout Chapter Four.

k) Public heath and safety – A number of activities proposed in this analysis have the potential to harm the general public. Because of this potential the Park has proposed that the island be closed to the general public during potentially harmful activities to protect public health and safety. These safety measures can be found in Chapter Four – Human Uses.

l) Sacred sites – The Park archeologist, through working with the Chumash tribe, has not identified any sacred sites on Santa Cruz Island as defined by EO 13007.

Alternatives Considered in Detail

Features Common to Alternatives 2-4

Ecological Monitoring

Monitoring and assessment of key ecosystem components is an action that is included in all alternatives. Pre-eradication surveys for baseline data of pig damage, flora and fauna abundance and distribution will be conducted. Post-eradication surveys of similar components would be conducted in order to measure ecosystem responses to the eradication of feral pigs and control of invasive species, such as fennel.

Control of Invasive Plants

The NPS intends to take action to control invasive plants on Santa Cruz Island regardless of which alternative is chosen. The purpose of weed control is to allow native plant communities to become re-established. If funds are available, the NPS would expand its current efforts to control weedy plants. It is expected that in the long term the extent of the weed problem would be greatest under Alternative One (No Action) and least under Alternatives

Two & Four (Eradicate pigs island-wide). NPS weed control efforts would focus primarily on the NPS-owned portion of Santa Cruz Island. However, the NPS plans to continue to work collaboratively with TNC to address island-wide weed problems.

Eradication of all non-native plants from Santa Cruz Island is not reasonably possible in the short term. Therefore, our goal is to reduce the density and distribution of weedy species sufficiently that it is a minor and non-dominant member of the island plant communities. The primary tool for control of non-native plants is to eliminate non-native animals and to allow native vegetation to recover and displace weedy species. However, there are some invasive weeds that would require focused treatment in order to control

The highest priorities for treatment are highly invasive weeds, outlier populations of weeds, weeds in sensitive habitats, and new invasions. Tools that would be used include digging, mowing, flower/seed head removal, and herbicides. Herbicides would be applied by hand, from a vehicle, or aerially using a helicopter. The herbicides to be used are Glyphosate (Round-up), triclopyr (Garlon 3A), glufosinate (Finale), and chlopyralid (Transline).

Fennel is a particularly high priority species for control because of its current extent and density. Dense stands of fennel would be controlled prior to eradication of pigs. The first priority for fennel control is to eliminate stands where fennel is the dominant plant in the community. These dense fennel stands are both an impact on native vegetation and hinder feral pig eradication efforts. The methods for controlling dense fennel stands is to burn them in the fall/winter of the year and apply Garlon 3A, an herbicide, to the stand in the following two springs. This protocol was developed by The Nature Conservancy in an extensive 600-acre program in the Central Valley of Santa Cruz Island.

Additional treatment of fennel in less dense stands and in outlying populations would be required to ensure that native plant communities do not become gradually overrun by fennel. The NPS and TNC propose to treat these situations by spot burning where appropriate, followed by herbicidal control, and spot treating with differing types of herbicides.

The prescribed burn would be conducted within the limits of a fire plan and prescription that describes both the acceptable range of weather, moisture, fuel, and fire behavior parameters, and the ignition method to achieve the desired effects. The prescribed burn for treating fennel would occur in the fall/winter of the year likely using both hand and aerial ignition.

Alternatives Considered in Detail

Alternative One - No Action

Under this alternative NPS would take no action to eradicate feral pigs from Santa Cruz Island or to promote the conservation of rare species, soils, or archeological sites beyond the level of action that the NPS is currently carrying out.

Pigs would continue to occur island-wide and population numbers would fluctuate with environmental conditions. Incidental control of problem animals or focused protection of sensitive resources would occur as staff time and funding permited.

Weed control would be restricted to current operational levels, which consists of opportunistic removal and spot spraying, but no comprehensive program. Fennel control would not be addressed.

There would be no specific mitigation of impacts, since this action would be a simple continuation of current operations.

Monitoring

Monitoring efforts would not change from current NPS levels and would be restricted to measures of community health, listed plant species population health, and vegetation type classifications.

Alternative Two – Simultaneous Island-wide Eradication of Pigs

Under this alternative the feral pigs would be eradicated from all of Santa Cruz Island. It is unlikely that pigs would be reintroduced to the island because of the distance to the mainland and the relatively low number of people visiting the island on private boats.

The goal would be to accomplish the eradication of feral pigs in a humane manner with as much speed and limited impact to the island as possible. In November 1998 the NPS and TNC assembled a group of biologists and land managers on Santa Cruz Island to discuss the issue of feral pig impacts and recommended management actions. The group unanimously determined that eradication of feral pigs should be of the highest priority for the management agencies due to the pervasive impacts of pigs on natural and cultural resources. The team also determined that an island-wide eradication was an achievable goal.

The eradication of feral pigs would likely be carried out by a combination of agencies or organizations. All personnel involved with this project would follow the mitigation measures described in this document for the protection of resources.

The primary tools for pig eradication would be the use of "walk-in" traps and trained hunters with dogs systematically pursuing pigs on the ground. Other techniques such as aerial hunting may be used when appropriate.

During the peak period of the pig eradication program it is estimated that a substantial increase in personnel, dogs, vehicles and ATV's would be on Santa Cruz Island. They would be housed, to the extent possible, in approved government housing on NPS owned property, and TNC facilities including, Central Valley facilities, and West End Facilities. Temporary tent camps may need to be established to facilitate operations in remote areas. Horses may also be used for transportation.

Under Alternative 2 the feral pig eradication project would occur in four phases:

The duration and success of each of the phases would depend on a number of factors, primarily: a) level of funding, b) environmental conditions, and c) pig population numbers.

Table 1: Alternative Two Pig Eradication Phases

Phase	Description
I.	*Administration and infrastructure acquisition (Approximately 1 year)*
II.	*Hunting (Approximately 2 years)*
III.	*Final Hunting (Approximately 1 year)*
IV	*Monitoring for Remnant Pigs (Five years)*

Phase I. Administration and Infrastructure Acquisition

This phase would require approximately one year to complete once funding is received and environmental compliance is met. This year

would be used to hire or contract with personnel, acquire trained pig dogs, purchase supplies and equipment, establish adequate communications on the island, and construct needed infrastructure.

Phase II. Hunting

A simultaneous island-wide operation would require several teams of hunters and dogs repeatedly working sections of the island. Hunters would be on the island for extended periods of time. Each team would have their own transportation, which could include pick-up trucks, "Jeep" type vehicles, ATV's, and/or horses to support their operation.

On Santa Cruz Island, ground hunting with dogs is the best general technique for the eradication program (Klinger pers. comm., Lombardo pers. comm.). Helicopter hunting works well in the wet season ~~and~~ along ridges in the winter. Trapping is successful with high densities of pigs and dense vegetation cover. These could be used in areas with "pig highways", during drought periods, or in fennel stands. Hunting over bait may also be useful in selected situations.

It is expected that the hunting teams would require approximately two years of continuous hunting island-wide to eliminate the pig population on the island.

Phase III: Final hunting

The final hunting phase begins after hunting teams have made at least three visits to all sections of the island and not seen sign or pigs.

During this phase, which would last one year, a reduced number of hunters and dogs would be maintained on the island. At least two people would be dedicated to searching the island to locate pigs or pig sign. Hunters would respond to the location of pig sign to assist the monitoring team. The project would move to Phase IV after the island had no detectable pig sign.

Monitoring for pig sign would continue throughout the life of the project. The primary purpose of the monitoring is to determine the presence or absence of pigs. Water sources, which are preferred habitat for pigs, would be a focus of the monitoring efforts.

Phase IV: Monitoring

This Phase would be an intensive period of combing the island to search for pig sign. Hunting teams and dogs would not be maintained on the island any longer. If sign is detected, hunters and dogs would be brought to the island once again. Monitoring would continue for five years following eradication of the presumed "last pig" in order to ensure that remnant pigs do not remain. Long term ecological monitoring to assess ecosystem changed due to pig eradication would continue into the foreseeable future.

Alternative Three - Eradicate Pigs on NPS Property; Exclude Pigs from Selected Sensitive Resources on TNC Property

Under this alternative the NPS would build and maintain a pig-proof boundary fence. Feral pigs would be eradicated from the 14,000-acre eastern portion of the island. It is expected that pigs would regularly re-enter NPS land by going through breaks in the fence, gates left open, or by going around the ends of the fence. NPS would have an ongoing program to maintain the fence, educate staff and visitors about the need to close gates, and to hunt pigs that get through or around the fence.

The eradication of feral pigs from NPS lands would primarily involve NPS personnel and a contractor. Techniques to be used for eradication would be similar to those described in Alternative 2. Trained hunters and dogs systematically pursuing pigs on the ground and

walk-in traps would be the primary methods used.

Island surveys for archeological sites and listed plant species are largely incomplete. Surveys by resource experts would need to be conducted and sites selected for protection. These selected sensitive resources would then have pig-proof fence constructed around them and pigs would be excluded from these areas. Known occurrences of federally listed plant populations would be fenced. The most important and threatened archeological sites would also be fenced. However, it is highly likely that some of the resources that fall into the category intended for protection would continue to experience degradation by pigs due to the inability to perform exhaustive inventories. Protective fencing would need to be continuously inspected and repaired to minimize damage from pigs.

Additionally, there are many resources of concern that are not formally listed under the Endangered Species Act or not known to be highly significant culturally that would remain vulnerable to impacts by pigs. However, we feel that to attempt to fence all important resources on TNC property is beyond the level of what could be funded or maintained over the long term. Therefore, efforts to exclude pigs from selected areas would be the primary protection for sensitive resources.

Alternative Four – Sequential Island-Wide Eradication by Fenced Zone Hunting

The directed action of this alternative would result in the complete eradication of feral pigs from Santa Cruz Island. In close coordination with The Nature Conservancy, approximately 45 miles of fence would be constructed, thereby splitting the island into 6 distinct management units of about 12,000 acres each (Figure 3). Hunting would occur in each of these management units on a sequential, basis. Complete eradication would be achieved in each of the units in a coordinated effort lasting approximately one year using trained, professional hunters. It is the goal of this project to complete this effort in a speedy, humane fashion to reduce prolonged impacts to the island during the eradication campaign. The establishment of fenced zones would allow greater flexibility in the duration of the overall program, however the risk of failure is increased substantially when the program is projected over many years. Mitigation measures dictated within this document would be followed by all personnel involved with the project and would be applied island-wide.

The techniques and tools for achieving the eradication goal would be similar to those described under Alternative Two, and are consistent with other models of eradication such as neighboring Santa Rosa Island, Santa Catalina Island and Hawaii Volcanoes National Park. Trained hunters aided by dogs would seek out and dispatch pigs on the ground, while the establishment of trap lines and sites using live "walk-in traps" would also be used. It is possible that a helicopter would be used to transport hunters or serve as a hunting platform.

This program would necessitate an increase in on-island personnel, jeep or truck style vehicles, all-terrain vehicles, and the use of hunting dogs. Other methods of transportation may also be used, such as horses or helicopters. Housing would utilize existing structures whenever possible, including government approved facilities on NPS owned property, and TNC facilities including, Central Valley facilities, and Christy Ranch. Temporary tent camps may also need to be established to ensure efficient operations in remote areas, such as boat-only accessible anchorages and rough, road-less terrain.

The eradication campaign would occur in four distinct phases, all similar to the phases found under Alternative Two. Each phase has discreet requirements for time to completion. A convened panel of experts has indicated that for the eradication to be successful, hunting must be complete within a ten-year window. If it is not, vegetation recovery from sheep grazing would severely reduce the ability of hunters to eradicate completely. Factors that could influence the duration of the project include but are not limited to: a) committed levels of funding, b) environmental conditions, such as rainfall, and c) pig population numbers. The detailed description of this alternative makes the assumption that sufficient funding would be provided to insure complete eradication.

Table 2: Alternative Four Pig Eradication Phases

Phase	Description
I.	*Administration and infrastructure acquisition (Approximately 1 year)*
II.	*Fencing (Approximately 2 years, overlapping with Phase III)*
III.	*Hunting (Approximately 6 years, beginning with completion of first fenced zone)*
IV	*Final Hunting and Monitoring (Five years)*

Phase I. Administration, Infrastructure, and Acquisition

Spanning approximately one year, this phase aims to build appropriate staff to oversee, manage, direct, and carry out the project including fencing and hunting contractors. Additionally, attention would be given to the infrastructure requirements for project implementation, such as bolstering current housing structures and establishing adequate communications on the island. Necessary equipment and supplies would also be secured at this time.

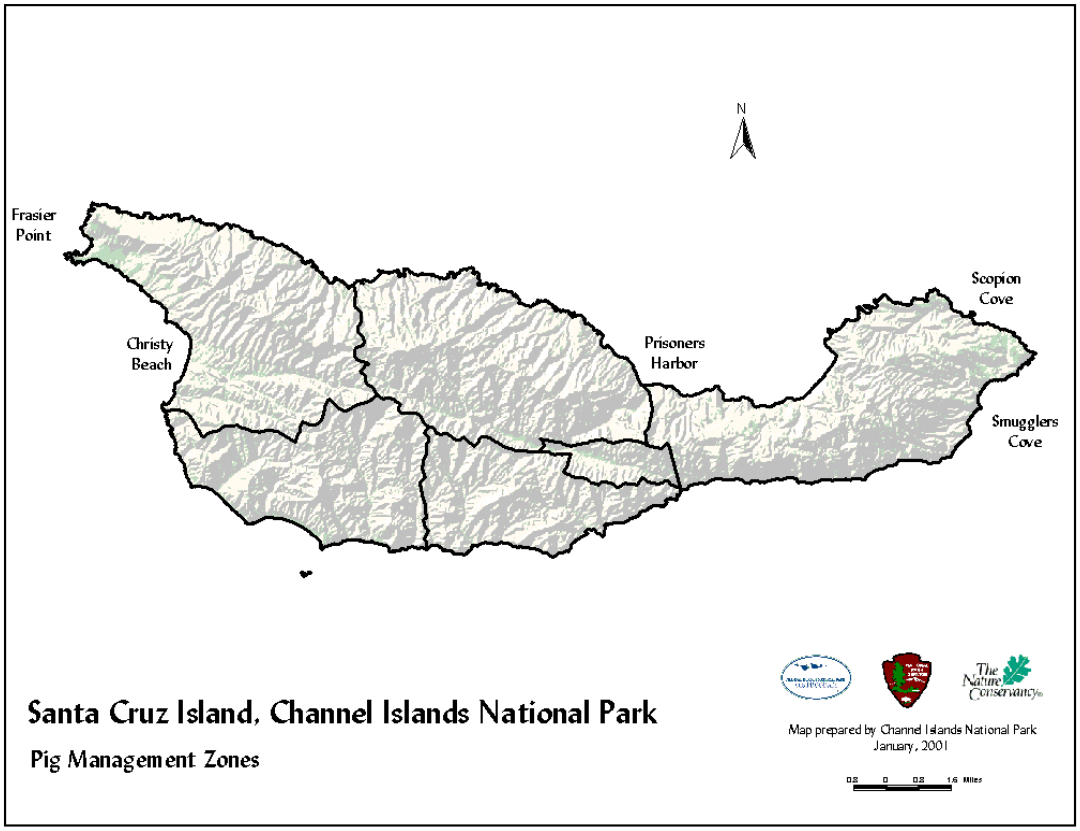
Phase II. Fencing

If all zones are constructed at once, fencing would require approximately 2 years to complete. The island would be fenced off into 6 distinct management units. Each zone is roughly 12,000 acres in size and designed to be hunted within a one-year time frame, barring factors listed above. Fences would be constructed of either triple-galvanized steel or special alloy metals to resist corrosion in the heavy marine environment of Santa Cruz Island. This type of fence has been demonstrated to be effective and durable in Hawaii Volcanoes National Park's efforts to date. Ideally, fencing would occur across all zones at one time, however, funding and logistics may not allow for all of the fencing to be completed prior to hunting in the zones. For instance, hunting and trapping in a zone may begin as soon as the zone fence is completed, and prior to the next sequential zone fence being completed.

Phase III. Hunting

Intensive hunting would occur in each of the defined management units as soon as fencing forming the perimeter of the zone is complete. This means that much of the fencing action and the hunting actions would be in operation concurrently. Generally, techniques such as trapping and baiting, as well as ground hunting with dogs have been shown to have the highest efficiency rate for eradication on SCI (Sterner, 1990). Following that model, zonal trapping could precede fence completion and ground hunting in each of the zones. By doing this, a rolling sequence of hunting zones is achieved and efficiency is increased. This reduces the

Figure 3. Alternative Four Hunting Zones for Pig Eradication



risk of failure from vegetation recovery and inability to locate remnant animals.

It is yet to be determined the sequential order of fencing and hunting/trapping for the zones. The factors that would be considered in determining the order of zone eradication activities include: a) risk of failure over time because of vegetation recovery, b) length and separation of defendable perimeter, and c) the need for preparation, such as fennel control within the unit. Continued monitoring of established pig-free zones would occur concurrently with the hunting efforts. Fence patrol for breaks and openings caused by pigs and weather would also be an ongoing task during this phase.

It is expected that the hunting team could achieve a nearly complete eradication status island-wide within a six-year period.

Phase IV. Final Hunting and Monitoring

The final phase of the program is perhaps the most important, as the intention is to exhaustively search the island for remnant pigs and pig sign. Hunting teams would no longer be maintained on the island, but would be dispatched to areas if sign or animals were detected. A systematic protocol of monitoring for remnant feral pigs wioulld be developed for the island. Concentrated efforts for monitoring would continue for five years after the completion of the last management zone. Monitoring of the island would continue for five years after elimination of the "last pig" in order to insure success. Long term ecological monitoring to assess ecosystem changes due to pig eradication would continue into the foreseeable future.

Alternatives Considered But Dismissed from Detailed Study

Live capture of feral pigs and relocation to the mainland

Feral swine, like all animals wild or domestic, are susceptible to a wide range of infectious and parasitic diseases. While some of these diseases are specific only to pigs, others are shared with other animals, including some that are shared with humans.

California is among the top states in the country for numbers of feral pigs. Currently, 52 of California's 58 counties are known to have feral pigs. As a statewide population, the number is great enough to cause substantial ecological impact, property damage, and further the spread of disease. As the numbers and distribution of feral pigs continues to increase, the contact between feral swine and domestic livestock, wild animals, and humans would also increase. This direct or indirect exposure to feral pigs brings with it a greater potential for transmission of both zoonotic (animal to human) and epizootic (animal to animal) diseases. To date, not a great deal of information has been compiled on the diseases of feral swine, let alone the mechanisms or rates of transmission into domestic animals or humans.

Of great interest in feral pig populations nationwide, as well as on Santa Cruz Island are the two diseases Brucellosis and Pseudorabies.

Brucellosis is a bacterial infectious disease of animals and humans that causes abortion and reproductive organ failure in the primary host, which in this case is the feral pig. In secondary hosts, such as humans, it can cause chronic flu-like symptoms, crippling arthritis, or meningitis. There is no cure for brucellosis for animals, while humans are treated with extremely high doses of antibiotics with the hope of clearing the infection. Brucellosis is transmitted via contact with fluids discharged from the infected animal (nasal mucous, semen, vaginal mucous, etc.).

Pseudorabies virus (PRV) is a herpes simplex epizootic disease that largely affects domestic livestock, cats, and dogs. The disease is spread primarily by direct contact and ingestion of infected tissues or carcasses. The symptoms of PRV vary widely among species, but can include: anorexia, excessive salivation, spasms and convulsions, as well as mad itch. PRV is almost always fatal.

Because of the wide-spread distribution of feral swine and their ability to spread brucellosis to humans and pseudorabies to domestic livestock and pets, federal disease eradication programs set-up for both diseases monitor actions involving feral pigs with grave concern. Millions of dollars have been spent in an effort to rid the United States of these livestock and human plaguing diseases. Therefore, agencies considering management actions that could increase the potential for transmission of these diseases is highly discouraged.

In light of this, both the State of California (1999) and the County of Ventura (1999) oppose transport of any live feral pigs from the island to the mainland. The California Department of Fish and Game stated "The Department would not approve a request to translocate wild pigs from Santa Cruz Island to the mainland. Our reasons for objecting to any plans to translocate wild pigs are two-fold: 1) potential spread of disease to other wild pigs or domestic swine, and 2) increasing the distribution and abundance of an exotic species with great potential of causing damage."

The County of Ventura (Jenks 1999) has stated that it would be "irresponsible to risk the health and welfare" of mainland domestic

livestock and pets by attempting to bring feral pigs from the island to the mainland.

The NPS concurs with this decision, opting to not risk transmission of potentially dangerous and fatal diseases to the mainland populations of domestic livestock, pets, and people.

Use of Poison

There are a number of toxicants which can be effective as part of an eradication program. However, each of the potential poisons could negatively affect non-target species. It would be very difficult to protect non-targets from incidental poisoning. Additionally, there are rare, endemic species, such as the island fox and spotted skunk, on Santa Cruz Island which would be threatened by increased mortality. For these reasons, and because hunting can achieve the park goal without the secondary impact, poison will not be used as a tool in the eradication of feral pigs from Santa Cruz Island.

Use of Snares

While snares are an effective and inexpensive method of trapping pigs, the use of snares on Santa Cruz Island would create the potential for capture of non-target animals such as the island fox or spotted skunk. Therefore, snares will not be used in this project.

Use of Contraceptives or Sterilization

Contraception and/or sterilization could be a relatively benign ways of eliminating feral pigs from an area. Unfortunately, birth control technology is not yet adequate to achieve eradication, or even control, of feral pig populations. The organization *In Defense of Animals* (1999) wrote "Currently there is not effective sterilization or contraceptives for feral pigs…"

Contraceptives are a tool that work adequately with species with low reproductive rates or animals that can be reliably treated with the contraceptive and booster at the required times and doses. Feral pigs do not meet either of these criteria.

The primary reason why birth control is completely ineffective with pigs is their high reproductive rate. Sows can produce 2 litters of pigs per year and average 5.6 pigs/litter on Santa Cruz Island. Sows begin breeding in their first year. With such a high reproductive rate, even the smallest failure of the contraceptive (the failure rate is approximately 20%) or not delivering the contraceptive and subsequent booster to every sow results in production of a large new generation.

Public hunting on NPS property

Allowing hunting by members of the public, similar to hunting in National Forests or on certain state lands has been suggested as an inexpensive way to eradicate pigs while raising revenues for the park. The primary reasons why this tool cannot be used as part of the eradication program are: A) there is no legal authority that could allow public hunting to occur in CINP, and B) public hunting, regardless of guide or not, cannot achieve total eradication of feral pigs on the island, a stated goal of this plan.

Recreational hunting can achieve significant control or eradication of animals that have a relatively low reproductive potential. However, animals with high reproductive potentials, such as pigs and rabbits, are much more difficult to eradicate and require a very focused and sustained effort by skilled workers.

Through recreation hunting, the former owners of eastern Santa Cruz Island attempted,

but failed, to control feral sheep numbers low enough to avoid extensive degradation of soils, vegetation and archeological sites on eastern Santa Cruz.

The decision by Channel Islands National Park to not use recreational hunting as a part of its work to eradicate pigs does not preclude The Nature Conservancy from allowing public hunting on its property prior to the eradication.

Use of Swine Diseases

Diseases, such as hog cholera, can be very effective in the reduction of pig populations. Hog cholera was introduced to Santa Cruz Island in the 1950's. It is thought that this resulted in a reduction of pig numbers on Santa Cruz Island by 75% or more. A survey conducted in the late 1980's confirmed that there is no remnant hog cholera left within the population of feral pigs on Santa Cruz Island.

Hog cholera has been successfully eliminated from the United States and is now classified as a foreign pathogen and disease. As such, hog cholera is not permitted for use in any capacity in the United States.

No swine diseases will be used on Santa Cruz Island because of the possibility of transmission of the pathogen to the domestic livestock, wild animals, or humans on the mainland.

Environmentally Preferred Alternative

The environmentally preferred alternative is the alternative that causes the least damage to the biological and physical environment.

For determining the least damage to the physical environment the Park compared the miles of fence construction across all alternatives. Alternative Two does not require building fence to eradicate pigs from the island. Whereas Alternatives Three and Four require 3+ and 41 miles of fence respectively.

There are similarities in the effects to biological resources for the three action alternatives (Alts 2-4), however, the persistence and duration of these effects is markedly different among the alternatives. For determining the least damage to biological resources the Park compared the duration the biological effects would persist among the alternatives. Alternative Two would complete pig eradication in approximately three years with the bulk of biological effects occurring during these years. Alternatives Three would be an on-going effort with biological effects persisting as long as control/eradication activities are conducted. Alternative Four would have biological affects persisting for up to six years, the lenth of time estimated to eradicate pigs from the island.

Because Alternative Two has less physical disturbance and would be completed in the shortest amount of time (least amount of biological effects) it is determined to be the "Environmentally Preferred Alternative."

Comparison of Alternatives

Table 3. Comparison of Alternatives

	Alternative One	***Alternative Two***	***Alternative Three***	***Alternative Four***
Pig Eradication Strategy	No Eradication Strategy would be implemented	Hunt all areas simultaneously until all pigs are eradicated	Create two pig zones: eradicate pigs in NPS zone; exlude pigs from selected resources on TNC property	Hunt and trap pigs by zone until all pigs are eradicated
Fence Construction (miles)	None	None	~10	~45
Duration of Project	0	4 years of eradication, 5 years inspect and monitor	2 years of eradication, exclude forever	6 years of eradication, 5 years inspect and monitor
Fennel Control	None	Prior to pig eradication - Burn Fennel in the fall; aerially spray with herbicide two consecutive springs	Prior to pig eradication - Burn Fennel in the fall; aerially spray with herbicide two consecutive springs	Prior to pig eradication - Burn Fennel in the fall; aerially spray with herbicide two consecutive springs
Likelihood of Success	None	Medium/High	Low	High

Santa Cruz Island Primary Restoration Plan

CHAPTER THREE

AFFECTED ENVIRONMENT

Introduction

This chapter focuses on portions of the environment that are directly related to conditions addressed in the alternatives. The description of the affected environment is not meant to be a complete description of the project area. Rather, it is intended to portray the significant conditions and trends of the resources that may be affected by the proposed project or its alternatives. Information in this chapter is based primarily on the Natural Resources Study conducted in 1979 by the Santa Barbara Museum of Natural History, inventory and monitoring data from the Park's resource management staff, information provided by The Nature Conservancy, U.S. Fish and Wildlife draft recovery plan for 13 plant taxa of the northern channel islands, independent academic research studies, and studies conducted as part of this proposed action. Other sources are noted where applicable.

This chapter is organized into four sections, which when taken together provide the most complete description of the island resources, including the human element. The four major components of this chapter are:

- Physical Environment
- Terrestrial Environment
- Cultural Resources
- Human Uses and Values

For the most part, geologic and climatological conditions, processes, and disturbances cannot be altered by management activities. Watershed, soil, and atmospheric conditions and processes, also part of the physiographic setting, can be modified by certain management activities, and such impacts are outlined in Chapter Four, Environmental Consequences.

Physical Environment

Setting

Off the coast of southern California, eight ridges in the continental shelf rise above sea level, forming a series of islands. The four northern islands are located in the Santa Barbara Channel parallel to the coast south of Point Conception; the four southern islands are scattered offshore between Los Angeles and the Mexican border.

The Channel Islands vary greatly in size, distance from each other, and distance from the mainland, creating an immense natural laboratory of isolation and evolution. Because the islands have escaped much of the historical human impact on coastal California, they provide and ideal place for field scientists to perform work no longer possible on the mainland.

Of all the Channel Islands, the largest and most diverse is Santa Cruz. Totaling 60,784 acres, Santa Cruz Island is almost three times the size of Manhattan. One of the northern Channel Islands, it lies southwest of the City of Ventura, 19 miles across the Santa Barbara Channel from the nearest mainland point.

The eastern end of Santa Cruz Island, including the area known as the "isthmus", is owned by the National Park Service. The Nature Conservancy owns the remainder of the island (Figure 1).

Like the state of California in miniature, SCI has two major mountain systems flanking a fault-dominated central valley. SCI's valley divides the island into two very different geologic terraines. To the north, a purple-brown ridge of young volcanic rocks rises to Mt. Diablo, then plunges abruptly into the Santa Barbara Channel. At 2,432 feet, Mt. Diablo is the highest point on all the Channel Islands. South of the central valley is a weathered ridge of reddish metamorphic rocks that reaches an elevation of 1,523 feet. At its seaward base, a submerged shelf extends several miles southward before falling off into the Santa Cruz Basin, which is more than a mile deep. Cutting through both ridge systems is a series of steep-sided canyons, many with freshwater springs and intermittent streams. Some of these creeks expire on gravel beaches at canyon mouths; others plunge from ocean cliffs directly into the sea. The island's main watershed has an interesting drainage pattern: Its primary stream flows southeast along the central valley, then turns abruptly northeast to drain through a steep gorge in the northern range to its mouth at Prisoners' Harbor.

The island's coastline includes a variety of exposures, from protected coves and sandy beaches to vertical cliff faces, hidden sea caves, and dissected marine terraces. Offshore, warm southern waters mingle with cold currents from the north, creating a major transition zone for marine life.

The diversity of the island's topography and microclimates gives rise to a wide array of habitats, from rocky intertidal to chaparral to pine forests. Its size and complexity make the island biologically similar to undisturbed areas on the adjacent mainland. But because of the SCI's geographic isolation, its ecosystems exhibit subtle and not-so-subtle differences from their mainland counterparts, inviting comparative studies.

The island's biota includes many organisms endemic to the Channel Islands, some found only on Santa Cruz Island. Scientists believe most plants and animals reached the island by chance after swimming, flying, or floating on debris, especially during periods of low sea level.

Considering that it was colonized by overwater dispersal, Santa Cruz Island supports a remarkably rich biota. Some groups, however, are decidedly depauperate, and certain organisms, lacking the usual competitors or predators, have taken on different forms or have invaded niches unavailable to them on the mainland.

Aboriginal people, who traveled extensively between the mainland and the islands, may have introduced some organisms. SCI's abundant, well-preserved archaeological sites provide insight into past cultures and environmental conditions. The island's seclusion, ruggedness,

and history of conscientious private stewardship have protected the island from many of the usual impacts of heavy exploitation following European contact.

Exotic plants and animals have affected the vegetation and soils of SCI. Ongoing efforts are being undertaken by all stewards of the island to deal with feral organisms. The most recent successful effort was the removal of over 9000 sheep from the island ending in December 2000.

Climate

Precipitation and Temperature

The Channel Islands enjoy the Mediterranean climate typical of the central California coast. Rain pelts the islands off and on from November to March, but is scarce from late May to October, when a stable Pacific high-pressure system settles off the coast. A shallow coastal marine layer helps lessen the impact of the common summer drought conditions on the islands.

Northwesterly winds blow throughout the year, picking up speed most afternoons and dropping off at night. These winds drive fog against the islands' northwestern slopes, which provide very different climatic conditions than the south-facing coastal slopes of the mainland. Santa Ana winds occasionally disrupt this pattern, particularly in the fall and early winter. These hot dry winds blow from the east when high-pressure systems are present in the interior mainland.

Drought

Drought is an important process that affects ecosystems. Drought is defined as an absence of usual precipitation (less than 75 percent of normal), for a long enough period that there is decreased soil moisture and stream flow, thereby affecting ecological processes and human activities. Drought conditions occur primarily during the summer months on Santa Cruz Island.

Geology

Much of the tumultuous geologic history of the Channel Islands can be read in the rocks of SCI (Gustafson, 1999). Cleaving the island in two is the Santa Cruz Island Fault, which juxtaposes 150 million-year-old metamorphic rocks with volcanics less than 20 million years old. Ongoing research suggests this fault has been very active recently, causing as much as 200-300 meters of movement in the last 30,000 years. This displacement can be seen in several areas where streambeds jog markedly as they cross the fault.

Formed by stream erosion along the fault zone, a pronounced but discontinuous central valley runs the length of the island from east to west, separating two major ridge systems.

Other features of geologic interest on SCI include sheep-induced erosion, diverse soils, unusual drainage patterns, and Pleistocene fossils of dwarf mammoths and Douglas fir.

Soils/Water Quality

This section will describe the current condition and trend of soil resources and water quality on Santa Cruz Island. However, because there has not been a soil survey nor permanent water quality stations established on Santa Cruz Island, information on these two subjects is not well documented. In cooperation with the Natural Resource Conservation Service, Channel Islands National Park has begun a soil survey for all Park islands, including Santa Cruz Island. This survey is expected to be complete within three years.

Geology and its Relation to Soil Erosion

Disturbance factors such as heavy past livestock grazing, pig rooting, and mass vegetation type changes when placed on steep landform

features and erosion prone sedimentary geologic types has caused localized downward trends in soil resources.

Gully and sheet erosion is still actively occurring throughout the island, especially within the sedimentary Monterey formations found on the islands isthmus and east end of the island. The El Niño storm events that took place during the winter of 1997-98 caused hundreds of small and large landslides throughout the island. As an example, the Scorpion watershed, one of the most disturbed watersheds on the island, is extremely vulnerable to erosion due to past heavy sheep grazing, pig rooting, steep landforms, and geologic type (half of the watershed is in the Monterey formation).

The volcanic geologic types found on the northwestern part of the island and on the higher elevations of the island's east-end are less prone to erosion. However, because this geologic type supports many of the tree-dominated community types, they have been a natural resting area for feral sheep, as well as pigs foraging for acorns. Even though they may be less prone to erosion, the feral animal activity has impacted them dramatically in local areas.

Watershed Features

Watersheds on Santa Cruz Island vary greatly in size. The largest watershed is the Central Valley, which runs east/west and drains out to the north shore at the base of the isthmus. Landforms within the watersheds vary, however almost all of them have steep slopes with highly dissected drainages.

Typical Santa Cruz Island watersheds are characterized by steep, highly dissected subdrainages. Most of the steep slopes show many mass slope failures that result in high erosion and sedimentation in the valleys. Most of the major watersheds have a mix of vegetation community types, with grasslands dominating the gentler slopes, and woodland communities in the higher elevations with steeper slopes. Incised gullies are commonplace throughout the drainages, a situation that was greatly exacerbated by the overgrazing of sheep. Slope failures of all sizes are also very evident throughout the watershed, although fewer slope failures are evident in watersheds that are in the volcanic geologic types.

Valley-bottom Characteristics

The highly dissected drainages are dominated by V-shaped valley-bottoms. Typically, the lower elevations near the ocean confluence valley-bottoms in the lower gradients tend to be U-shaped drainages. The V-shaped drainages are highly efficient at delivering sediment. These valley-bottom types, when coupled with low vegetation cover are capable of causing "flash flood" events. This situation contributed to the December, 1997 Scorpion Flood.

Streamflow and Water Quality

Most drainages have only intermittent above ground stream flow. However, the larger watersheds have perennial flow in normal precipitation years. Drought conditions play a major role in extent of above surface streamflow. Even the largest watershed on the island (Central Valley) has intermittent flow, where stream flow alternates above and below ground throughout its length. Junak et. al. (1995) notes that there are many freshwater seeps and springs throughout the island. One of the largest springs on the island is located in Aguaje Canyon near Yellowbanks Anchorage. There are no known records of water chemistry (nutrients or animal waste) monitoring within the streams of Santa Cruz Island, however, with the historical ranching influence on upland watershed vegetation conditions, sedimentation above natural sediment rates is a concern for water quality.

Terrestrial Environment

Introduction

This section provides a description of the terrestrial component of Santa Cruz Island that is directly related to conditions addressed in the alternatives. As such, it is not a complete description of the entire terrestrial environment; rather it is a description of the significant conditions and trends of resources that may be affected by the proposed project or its alternatives. Listed below are the three terrestrial components that will be described in this section:

- Wildlife
- Native Vegetation, including Threatened and Endangered plant species
- Fennel and other weeds

Wildlife

Introduction

Santa Cruz harbors fewer species than comparable mainland areas, because only a subset of the mainland species pool successfully colonized the island. This is typical of island faunas. On the other hand, evolution of island forms in relative isolation from their mainland ancestors has resulted in a high degree of endemism in the fauna of Santa Cruz Island, and for the fauna of islands as a whole. Endemic taxa (species or subspecies) are those that are restricted to a particular geographic locale.

Non-avian Vertebrates

Eight species of reptiles and amphibians have been recorded for Santa Cruz Island (Table 4), of which 3 are endemic to the island or archipelago. One reptile, the Santa Cruz gopher snake, occurs only on Santa Cruz and Santa Rosa Islands. Thirteen species of mammals, including 9 species of bats, have been recorded on Santa Cruz (Table 4). Three of the 4 non-bat mammals occur only on Santa Cruz, and the other (the island spotted skunk) occurs only on Santa Cruz and Santa Rosa Islands.

Because of their unique taxonomic status and questionable population status, several species are treated in greater detail.

Island Spotted Skunk

Island spotted skunks (*Spilogale gracillis amphiala*) occur only on Santa Cruz and Santa Rosa Islands, having possibly been extirpated from San Miguel Island (Walker 1980). Very little is known about the ecology of the Channel Islands spotted skunk. Difficulty in trapping skunks has plagued the few investigations that have been attempted. Crooks (1994) studied the comparative ecology of the spotted skunk on Santa Cruz Island in relation to the island fox. He found that skunks were rare and difficult to capture; that they were habitat specialists, preferring ravines, and to a lesser extent, chaparral-grasslands; and that they were entirely carnivorous and nocturnal. Crooks concluded that the low population size and relatively narrow geographic range of the skunk made the species vulnerable to extinction.

The skunk is listed as a "Species of Special Concern" by the State of California and the National Park Service. According to von Bloeker (1967), spotted skunks were once very common on Santa Cruz and Santa Rosa Islands, but by 1967 they were rarely found on either island, at least near human dwellings. The apparent rarity of spotted skunks may reflect normal population fluctuations, or it may reflect a real decline in numbers (Williams, 1986).

Recent observations from Santa Cruz Island and Santa Rosa Island indicate that island spotted skunks have increased in numbers, at the same time that island foxes have decreased (G. Roemer, Institute for Wildlife Studies, unpublished data; K.

Table 4. Santa Cruz Island Fauna

Common Name	*Scientific Name*[1]	Legal Status[2]	Endemic Status
AMPHIBIANS			
Blackbelly slender salamander	*Batrachoseps nigriventris*		
Channel Islands slender salamander	*B. pacificus pacificus*	FSC	Channel Islands
Pacific tree frog	*Pseudacris regilla*		
REPTILES			
Southern alligator lizard	*Elgaria multicarinata*		
Island fence lizard	*Sceloporus occidentalis beckii*		Channel Islands
Side-blotched lizard	*Uta stansburnia*		
Santa Cruz gopher snake	*Pituophis catenifer pumilus*	FSC, CSC	SCI, SRI
Western yellowbelly racer	*Coluber constrictor mormon*		
MAMMALS			
California myotis	*Myotis californicus caurinus*		
Big-eared myotis	*M. evotis*	FSC	
Fringed myotis	*M. thysanodes*	FSC	
Townsend's western big-eared bat	*Corynorhinus townsendii townsendii*	FSC, CSC	
Big brown bat	*Eptesicus fuscus*		
Pallid bat	*Antrozous pallidus pacificus*	CSC	
Silver-haired bat	*Lasionycteris noctivagans*		
Hoary bat	*Lasiurus cinereus*		
Red bat	*L.borealis*		
Mexican free-tailed bat	*Tadarida brasiliensis*		
Western mastiff bat	*Eumops perotis californicus*	FSC, CSC	
Santa Cruz Island deer mouse	*Peromyscus maniculatus santacruzae*		Island
Santa Cruz Island harvest mouse	*Reithrodontomys megalotis santacruzae*	FSC	Island
Santa Cruz Island fox	*Urocyon littoralis santacruzae*	ST, FSC	Island
Island spotted skunk	*Spilogale gracilis amphiala*	FSC, CSC	SCI, SRI

[1]Nomenclature for reptiles and amphibians is from Collins (1990).
[2]FSC = Federal Species of Special Concern; CSC = California Species of Special Concern; ST = State-listed as Threatened. Data on legal status is from California Department of Fish and Game (1998).

Crooks, University of California, Santa Cruz, pers. comm., T.Coonan, NPS, Unpublished Data).

Island Fox

The island fox (*Urocyon littoralis*), a diminutive relative of the gray fox (*U. cinereoargenteus*), is endemic to the California Channel Islands. It is distributed as six island populations each varying in size from less than a hundred to a few thousand individuals. The fox exists as a different subspecies on each of the six islands, a distinction upheld by morphological and genetic work (Wayne et al. 1991, Collins 1993). The subspecies on Santa Cruz Island is *U. l. santacruzae*. Due, in part, to its limited distribution and small numbers it has been listed as a threatened species in California (California Department of Fish and Game 1987) and was formerly considered a candidate for listing as a federally threatened or endangered species (Federal Register 1989). A substantial amount is known about this species' population ecology and evolutionary history due to recent work on island fox genetic variability (Gilbert et al. 1990), evolution (Wayne et al. 1991), disease incidence (Garcelon et al. 1992), and population status and conservation (Roemer et al. 1994, Roemer 1999). Channel Islands National Park

encompasses five of the eight California Channel Islands and includes three islands that harbor different island fox subspecies.

Island foxes occur in virtually every habitat on the Channel Islands and feed on a wide variety of prey (Moore and Collins 1995). They occur in valley and foothill grasslands, southern coastal dune, coastal bluff, coastal sage scrub, maritime cactus scrub, island chaparral, southern coastal oak woodland, southern riparian woodland, Bishop and Torrey pine forests, and coastal marsh habitat types. Island fox home range size varies by habitat type, season and sex of the animal (Fausett 1982, Laughrin 1977, Crooks and Van Vuren 1995, Thompson et al. 1988, Roemer 1999). The island fox diet includes a wide variety of plant and animal materials (Collins 1980; Laughrin 1973, 1977, Crooks and VanVuren 1995; Moore and Collins 1995). Island foxes forage opportunistically on any food items encountered within their home range. Selection of food items is determined largely by availability, which varies by habitat and island, as well as seasonally and annually. Principal foods eaten include mice, ground nesting birds, arthropods, and fruits.

Island fox populations on Santa Cruz and San Miguel Islands have been annually monitored since 1993. The island fox population on San Miguel declined beginning in 1994 (Coonan et al. 1998) with the adult population falling from 450 in 1994 to 15 in 2000. The Santa Cruz population declined from approximately 2000 adults in 1994 to perhaps less than 135 in 2000 (Roemer 1999). Survey data from Santa Rosa Island (G. Roemer, Institute for Wildlife Studies, unpublished data) indicate that island foxes are undergoing similar catastrophic declines on that island as well. Using population viability analysis, Roemer (1999) estimated time to extinction at five years for island foxes on San Miguel and 12 years for island foxes on Santa Cruz. Populations are so low that the National Park Service has broadly supported a petition to U. S. Fish and Wildlife Service to list the species as endangered under the Federal Endangered Species Act.

Predation by non-native golden eagles (*Aquila chrysaetos*) is the primary mortality factor now acting upon island foxes on the northern Channel Islands, and is likely responsible for the massive decline of the past five years (Roemer 1999). Golden eagle predation was identified as cause of death for 19 of 21 island fox carcasses found on Santa Cruz Island from 1993 to 1995 (Roemer, unpublished data). On San Miguel Island in 1998-1999, four of eight radiocollared island foxes were killed by golden eagles in a four-month period, and another two died of unknown causes (T. Coonan, unpublished data). This level of golden eagle predation is unnatural. Until recently, golden eagles have never bred on the Channel Islands and their recent appearance is due to a prey base, feral pigs (*Sus scrofa*) that was not present prehistorically.

The absence of bald eagles (*Haliaeetus leucocephalus*), which bred historically on the islands and whose presence may have kept golden eagles away, is another contributing factor driving increased golden eagle predation. Moreover, on much of the northern Channel Islands, historic sheep grazing changed the predominant vegetation from shrub to non-native grasslands, which offer much less cover from aerial predators.

Concerned about the potential loss of three subspecies of island foxes from its lands, the Park convened an island fox recovery team in April 1999 to consider the available information and develop strategies to recover island fox populations to viable levels. The team concluded that:

- predation by golden eagles is the primary mortality factor now acting on the population
- disease or parasites may be compounding the effects of predation
- natural recruitment is low
- the most effective conservation measure that could be taken right now is to increase survival of pups, juveniles and adults by reducing or eliminating golden eagle predation

The team recommended that the Park implement the following emergency measures to safeguard island foxes and to recover fox populations on the northern Channel Islands:

- Relocate golden eagles from the northern Channel Islands
- Establish fox sanctuary/captive breeding programs on Santa Rosa and San Miguel Islands
- Eradicate feral pigs
- Reintroduce bald eagles

Upon receiving these recommendations, the Park began taking emergency recovery actions in 1999. In summer 1999 the Park constructed pens on San Miguel and began capture of wild island foxes. By January 2000, 14 island foxes had been captured and placed in the pens. Only four of those are males, and so eight San Miguel Island foxes were paired for breeding purposes. It is estimated that there is only one fox left in the wild on San Miguel Island. A captive breeding program has also been initiated for Santa Rosa Island and 22 foxes are now in captivity on the island, and less than 5 are thought to exist in the wild.

The Park also established a cooperative agreement with the Santa Cruz Predatory Bird Research Group (SCPBRG) in 1999 for the purpose of initiating golden eagle removal from the northern Channel Islands. Personnel from the SCPBRG began eagle surveys on Santa Cruz Island, the island with the most recent sightings, in late summer 1999. During that time period a helicopter crew working on East Santa Cruz Island noted a large stick nest in a canyon. Biologists from SCPBRG rappelled into the nest and confirmed that it was an active golden eagle nest. Among the prey remains found in the nest were two adult island foxes, piglets, and ravens. Two adult birds and two immatures, their presumed young of the year, were seen in the area. Eagle sightings from other parts of Santa Cruz indicate that there may be as many as three breeding pairs, and a total of 10-12 golden eagles on that island, and two to three on Santa Rosa. In October 1999, another radiocollared fox was killed by golden eagles on San Miguel Island. The park initiated golden eagle removal in the fall of 1999, and to date have removed and relocated 13 birds to habitat in the northeastern Sierras of California and a handful remain on the island. However, other golden eagles may move in from the mainland and take their place, so the program will be an ongoing task that will be continued until all eagles are removed.

Landbirds

Fifty-one species of landbirds are known to breed on Santa Cruz Island (Diamond and Jones 1980). Eight of those taxa are subspecies endemic to two or more of the northern Channel Islands, while one, the island scrub-jay, is a species endemic to Santa Cruz Island. Three of the endemics (horned lark, rufous-crowned sparrow, and loggerhead shrike) exist at low population levels (H. Walter, University of California, Los Angeles, unpubl. data).

Several pairs of peregrine falcons, a species formerly listed as endangered, breed annually on the island. Bald eagles are currently listed as threatened under the Endangered Species Act, but have been proposed for de-listing. They formerly bred on Santa Cruz Island, and on all other Channel Islands, but were extirpated in the mid-20th century due to persecution and effects of DDT and other related compounds (Kiff 1980).

Invertebrates

The invertebrate fauna of Santa Cruz Island is much less well known than the vertebrate fauna, due to greater traditional interest in the latter, and the far greater number of taxa in the former. Powell (1994) estimated that lepidopteran fauna of Santa Cruz Island was about 70-75% known. In contrast, San Miguel and Santa Rosa lepidopteran fauna was only 50% known. About 750 species of lepidopterans are known from the Channel Islands, about 550 of them from Santa Cruz Island. Fourteen

lepidopteran species from Santa Cruz are endemic to one or more of the Channel Islands (Powell 1994). The butterfly and moth fauna of Santa Cruz Island is depauperate, for the same reasons that island vertebrate species are typically depauperate: absence at time of island genesis, subsequent extinction, and failure to colonize (Powell and Wagner 1993).

The native bee fauna of Santa Cruz Island is well known, due to research on the effect of non-native European honeybees (*Apis mellifera*) on native bees (Thorp et al. 1994). The bee fauna of Santa Cruz is more diverse than that on other Channel Islands, due to the island's size, elevations, topographical diversity, and habitat variability. European honey bees have been all but eradicated from the island (Wenner et al., in press).

Non-Native Pigs

Feral or domestic pigs (*Sus scrofa*) are an ungulate species not native to North America. Domestic pigs were brought to California by Spanish settlers in 1769 (Barrett 1999) and were introduced to Santa Cruz Island in 1852 (Schuyler 1988). The term "feral pig" refers to a wild pig that comes from domestic genetic stock, such as domestic livestock that escape to survive in the wild, as well as their progeny. By 1857 pigs had escaped and become feral on Santa Cruz Island. Wild pigs now occur in 52 of 58 California counties and are most abundant in forests, oak woodlands and chaparral.

Feral pigs are generalist omnivores with a diet that changes seasonally according to abundance of foods. Mast foods, such as acorns and berries, are important food items in the fall. Winter diets typically comprise roots, bulbs and invertebrates that pigs find by rooting in seasonally moistened soil. As soil dries during spring and summer, pig diets shift to green plants.

Feral pigs have high reproductive potential, and are considered the most prolific ungulate in the U.S. Sows can breed at six or seven months of age, and can produce up to two litters per year with as many as 10 piglets in each litter. Pig populations can double annually if not limited by food or water availability. Pig populations respond to changes in food availability and weather. Drought years can cause significant declines in population numbers due to starvation and reduced reproduction, whereas heavy mast crops following winters of high precipitation can allow pig populations to increase significantly (Baber and Coblentz 1987, Sterner 1990). Pigs generally require access to permanent water, and abundant cover.

Feral Pigs on Santa Cruz Island

Most information about pig distribution and abundance on Santa Cruz Island comes from studies initiated in the 1980's. Feral pigs are found in all locations and habitat types on Santa Cruz Island (Schuyler 1988). As in other areas, they favor oak woodland throughout the year, but especially during the fall when the acorn crop is available. Pig utilization of chaparral and grassland habitat types increases during the winter and spring when grasses and forbs are emerging. Coastal areas are least utilized, year-round. Ridge tops and higher slopes are utilized primarily during the wetter, cooler months. During the dry months pigs are typically found in canyon bottoms or mid to low slope.

Reasonable pig population estimates for Santa Cruz Island were not available until the 1980's, although it is generally accepted that the removal of feral sheep from the island increased both vegetative cover and the carrying capacity for feral pigs (Babbler 1982, Sterner 1990). Annual estimates of the island's pig population have ranged from 1500 to over 4000.

As an example of the large population swings that Santa Cruz Island pigs endure, a study by Sterner (1990) estimated the island population at 1261 in 1987, based upon island wide aerial and ground censuses. Because the censuses occurred after drought and hunting-induced mortality, the actual spring-summer pig population was thought to be higher than this. The pig population apparently

doubled from 1987 to 1988, due to an increase in mast production, which included scrub oak (*Quercus dumosa*), island manzanita (*Arctostaphylos insularis*) and Catalina cherry (*Prunus ilicifolia lyonii*) (Sterner 1990). An aerial census in 1988 yielded an island pig population estimate of 3165 ± 1157. Pig densities were estimated at 15 – 24 pigs per km^2. Average litter size increased from 1.1 piglets per sow in 1987 to 3.2 in 1988.

Santa Cruz Island pig densities were found to be higher than densities reported from mainland sites in California (Sterner 1990). One reason for this may be lack of predators on the island; another is the smaller size of Santa Cruz Island pigs. Sterner (1990) reported that adult pigs on Santa Cruz Island weighed about half as much as mainland pigs.

Sterner (1990) also conducted a radiotelemetry study of feral pigs in the Willows Pasture of Santa Cruz Island to determine home ranges and habitat utilization. He found pigs to prefer drainage bottoms, which pigs used as travel corridors, to ridge tops. Pigs selected areas close to cover and water sources. The Willows pasture was sufficiently heterogeneous that pigs did not prefer one habitat type over another.

All feral pigs were removed from a 4500 ha exclosure in the Willows Pasture on Santa Cruz Island from 1989-1990, to evaluate the feasibility of eradication (Sterner and Barrett 1991). Feral pigs later breached the fence and recolonized the area.

Diseases of Feral Pigs

Wild and feral pigs can harbor various diseases, including pseudorabies, hog cholera, brucellosis, vesicular exanthema of swine (also known as San Miguel sea lion virus), trichinosis, and leptospirosis. Most of these diseases have been eradicated, or are highly limited in extent, on the California mainland through extensive inoculation programs. Recent sampling of the population indicates very low incidences of disease, if any, to occur. However, disease sampling can only provide guidance for trends, not comprehensive prevalence for disease within a population. Clearly, the potential for disease within the wild population of pigs is still quite large, especially within the context of high incidences of disease in the past.

Hog cholera is the most destructive and costly swine disease ever to occur in the U.S., but was eradicated by 1978. Hog cholera was introduced into both Santa Cruz and Santa Rosa Island pig populations earlier in the century in an attempt at eradication, but serologic testing of blood from island pigs in 1987 revealed no antibodies to hog cholera in that sample (APHIS 1988).

Pseudorabies virus is a herpes virus that causes pseudorabies infection (also known as Aujesky's disease, mad itch, and infectious bulbar paralysis). Most mammalian species are susceptible to infection, but pigs, which are the only reservoir for the virus, are most susceptible (Vandevelde 1990). The virus does apparently not affect humans. Transmission among pigs is direct, and can be venereal, since the boar sheds the virus in his semen. Transmission among pigs is also density dependent, with more transmission, and higher prevalence of the disease at higher pig densities (Timm et al. 1994). Consuming contaminated raw pork can infect other mammals, particularly fur-bearing mammals, dogs, and cats. Pseudorabies is nearly always fatal in dogs. Pseudorabies can become enzootic in some pig populations, with few adverse effects at the population level. Alternatively, pseudorabies can cause up to 100% mortality in suckling pigs (Gustafson 1986, as cited in Timm et al. 1994). Mortality is much less in adult pigs, but effects include anorexia, weight loss and reproductive failure.

Antibodies to pseudorabies virus were detected in pig blood samples from both Santa Cruz and Santa Rosa Islands in the 1980's, prompting the Secretary's Advisory Committee on Foreign Animals and Poultry Diseases to recommend against live removal of pigs from those islands to the mainland (Glosser 1988). On Santa Catalina Island, 25% of 366 pigs tested positive for

antibodies to pseudorabies (Timm et al. 1994), with adults having higher seroprevalence than juveniles. Effects of the disease on individuals and the population were not apparent. Seroprevalence (the presence of antibodies) indicates exposure to a disease, but does not necessarily equate to infections.

Brucellosis is a disease caused by bacteria of the genus *Brucella* that can cause reproductive failure in the form of abortions and reproductive organ infections (Davis 1999). The disease is zoonotic, or capable of being transmitted to humans, in whom it can mimic severe flu and may lead to crippling arthritis or meningitis. Animals and humans are exposed to the *Brucella* bacterium by handling or contact with infected placentas, amniotic fluids, vaginal discharges, milk semen, reproductive tissues, and exudates from infected animals usually just prior to and after an abortion. *Brucella suis* specifically affects pig populations. Other species include *B. canis*, which causes canine brucellosis, and *B. abortus*, which affects large ungulates such as bison and elk. It is not known whether feral pigs on Santa Cruz are infected with brucellosis. Timm et al. (1994) found no antibodies to brucellosis in Santa Catalina Island pig blood samples. In a survey of feral swine in California, 3.8% of 611 pigs were seropositive for brucellosis (Drew et al. 1992), but 90% of those positive animals were from only two counties. Brucellosis is thus locally influential in several pig populations in California.

San Miguel sea lion virus is a calicivirus which, in pigs, results in lesions identical to those produced by vesicular exanthema of swine disease. Antibodies for San Miguel Sea lion virus have been found in serum from both feral pigs and island foxes on Santa Cruz Island (Prato et al. 1974, 1977), and in pigs on Santa Catalina Island (Timm et al. 1994). Vesicular exanthema of swine and San Miguel sea lion virus in foxes may have a marine origin on Santa Cruz Island (Prato et al. 1974, 1977), since pigs and foxes forage at pinniped haul-out sites.

Trichinosis is a zoonotic disease caused by the parasite *Trichinella spiralis* and passed to humans by the consumption of infected, undercooked meat. It is very rare in wild pigs in California, with only a 1% occurrence (Jessup and Swift 1993). It is not known if Santa Cruz Island pigs have significant infection with *Trichinella*.

Leptospirosis is a zoonotic disease caused by a bacterium, *Leptospira interrogans*. The bacteria are shed in pig urine, and can be transmitted to other animals at watering holes in which pigs have wallowed. The period of active infection is brief and *Leptospira* is only viable in water for a short time (Jessup and Swift 1993). However, antibodies to *Leptospira* are common (83%) in California pigs.

Pig Management in the State of California

The California Fish and Game Commission in 1956 declared wild pigs a game mammal, and since that time pig range, hunter interest and annual kill have expanded (Barrett 1999). With current wild pig numbers in California estimated at 70-80,000, the species is nearly as important a big game species as deer. However, problems with pig depredation exist statewide, and the state of California must balance its management of the pig as a game animal with the need to control pig damage on public and private lands (Updike and Waithman 1996).

Based upon his observation of pig distribution and abundance on Santa Cruz Island, Sterner (1990) stated it was unlikely that sport hunting could control pig populations, unless the annual take was more than 50% of the pig population. Barrett (1999 pers comm) later stated that it was likely that 70% of the population would need to be removed on an annual basis to maintain a low and stable number of pigs on the island.

Pig Eradication Efforts

Feral pigs have been successfully eradicated from areas using a variety of methods, including traps, hunting, and hunting with dogs, and with boundary fencing to limit future incursions of pigs

(Barrett et al. 1988; Sterner and Barret 1991). These are the primary tools used in the successful eradication campaign underway on neighboring Santa Catalina Island, as well as the model being used in Hawaii Volcanoes National Park.

Native Vegetation

Introduction

The vegetation communities on Santa Cruz Island, like those of the other Channel Islands, developed in relative isolation from the mainland. Although many species on the islands are the same as those found on the mainland, almost 50 are unique to the Channel Islands. These endemic species can be confined to one or more of the islands. Some of these endemic species are believed to have developed on the islands through adaptive radiation (Sauer, 1988). Other Channel island endemic species are remnants from more widespread populations that once occurred on the mainland. Aside from long-term climatic changes these vegetation communities developed in the absence of major disturbance pressures until the arrival of human inhabitants 8900 years before present (B.P.). The first human inhabitants were probably Native Americans who reached the islands from the mainland. Archeological evidence indicates that sizable human populations were present on all of the larger Channel Islands by about 7000 B.P. There is little doubt that these first inhabitants altered the vegetation on the islands in some fashion. It is likely that they exerted an impact on island vegetation through food-gathering activities. They may have deliberately set fires to encourage certain plants to grow and for easier access through and to certain areas. They may have also cut down trees or shrubs for shelter, for fuel, and to make baskets. Because these early inhabitants were mobile and likely moved from island to island, and to and from the mainland, they may have also, inadvertently or deliberately, introduced new plants and animals to the islands.

Even with the impacts associated with early Native American habitation of the islands, it probably wasn't until the arrival of European traders around the mid-eighteenth century that the island vegetation became seriously altered. It was during this era that goats, pigs, and sheep were variously released on some or all of the islands. Left alone, these animals became feral and the lack of predators on the islands allowed them to quickly reproduce. As their numbers grew, these alien herbivores severely impacted the native vegetation and probably extirpated many plant species, which had developed for thousands of years isolated from grazing. By the 1830's settlers had moved on the islands to farm and raise livestock. Rabbits were released on some of the islands to be followed by cattle and more sheep. These settlers also brought with them non-native plant species, many of which were adapted to the pressures of grazing and consequently thrived at the expense of the native vegetation in the presence of the introduced herbivores.

Santa Cruz Island Vegetation

Sheep were first introduced to Santa Cruz Island around 1850. Their numbers on the island were allowed to grow fairly unchecked with periodic round-ups to shear and slaughter some of the stock. By 1875 there were an estimated 60,000 sheep on the island, only half of which could be rounded up for shearing annually (Sauer, 1988). During drought years tens of thousands were slaughtered to forestall starvation. These haphazard attempts at management of the stock continued until 1939 when the Stanton Ranch, who had acquired 90% of SCI in 1937, began a concerted effort to install fencing and to round up all the sheep. By the 1970's over 263,000 sheep had been captured and sent to market or slaughtered (Warren, ca 1954; Santa Cruz Island Company Records). Due to the severe grazing that had occurred, coastal prickly

pear (*Opuntia littoralis*), a native cactus and component of island coastal bluff scrub, began to expand. By 1939 the Stanton Ranch estimated that 40% of the rangeland on the island was useless because of dense *O. littoralis* stands. The ranch then enlisted the help of entomologists from the University of California, Riverside and began releasing biological controls to control the Opuntia. Although several insects were released, the most successful was a cochineal bug, *Dactylopius opuntiae*, which since 1951 has destroyed most of the dense *Opuntia* populations on the island (Sauer, 1988).

In 1978, The Nature Conservancy secured permanent protection for the Stanton holdings and began a more intensive program of fencing, trapping, and hunting to remove the remaining feral sheep on the Stanton portion of the island. In 1987, Carey Stanton died and the Nature Conservancy became the sole owner and manger of 90% of Santa Cruz Island. Not long after, The Nature Conservancy completed its sheep eradication program. The Nature Conservancy then ceased what had been the Stanton ranching operation and removed all of the cattle from the island. At this juncture, the remaining herbivores on the island were feral pigs and sheep. The feral sheep were, for the most part, confined to the eastern 10% of Santa Cruz Island. In 1997 the National Park Service fully acquired the eastern 10% of Santa Cruz Island (ESCI). ESCI was incorporated into Channel Islands National Park, which began removing the estimated remaining 9000 sheep within its boundary. The National Park Service concluded an intensive 3-year effort to remove sheep from Santa Cruz Island. This effort has successfully removed approximately 9,270 sheep from the island. At publishing time of this document it is believed that Santa Cruz Island is sheep-free, however, vigilant monitoring for remaining sheep is on-going. Feral pigs are now the only introduced animal species left on SCI.

The severe grazing pressure that has occurred on SCI over the past 150 years has adversely affected most of the island's plant communities by altering their population structure, the natural size and stature of dominant species, as well as species diversity and composition (Hochberg et al., 1980). Grazing of selected plant species has reduced the range of many native species (e.g. *Coreopsis gigantea, Hazardia detonsa*, *Lupinus albifrons*, and *Mimulus flemingii*) and increased the range and abundance of other taxa (e.g. *Eremocarpus setigerus*, *Opuntia littoralis*, *O. oricola*, *Senecio flaccidus*) (Junak et al., 1995). The adverse effects of feral sheep and pigs on Santa Cruz Island has been well documented (Hochberg et al., 1980; Goeden et al., 1967; Van Vuren and Coblentz, 1987). At the east end of the island, adverse impacts to vegetation were noted by Brumbaugh (1980b) by comparing maps drawn in 1856 with aerial photographs taken in 1929.

The vegetation on SCI is to a large degree determined by the island's topographic and geologic factors. The underlying geology of SCI is dominated by Santa Cruz Island Volcanics overlain with eroded Pleistocene terrace deposits. ESCI for the most part rises abruptly out of the ocean and its interface with the ocean is dominated by steep cliffs, covered by coastal bluff scrub. Away from the cliffs the topography flattens out and annual grasslands dominate on these coastal terraces. As one moves towards the isthmus, which links ESCI with the main portion of Santa Cruz Island, the topography becomes quite steep and patches of island chaparral, oak woodland, and ironwood groves occur. Originating from these steep slopes are riparian drainages which have cut through the coastal terraces as they outlet to the sea. To the west of these steep slopes lies the isthmus. Here most of the bedrock is composed of cherts and diatom-rich shales from the Monterey Formation. This material erodes readily into a reddish, clay-like soil (Schoenherr et al., 1999). Island chaparral and oak woodland are the dominant vegetation communities on the isthmus. The rest of SCI is characterized by a large central valley, which skewers the main part of the island on a diagonal. The valley is bordered by gentle to steep slopes to

the north and south. This topography is overlain with a mosaic of plant communities.

Different authors have variously described the vegetation communities on SCI. Philbrick and Haller (1977) noted eight upland plant communities and two wetland vegetation types. Minnich (1980) in turn reduced the island's vegetation communities into six physiognomic categories by combining some categories and discarding others. In contrast, Holland (1986), expanded the island plant communities into 14 different types: southern foredune, southern dune scrub, southern coastal-bluff scrub, Venturan coastal-sage scrub, valley needlegrass grassland, non-native grassland, island chaparral, island-oak woodland, southern Bishop-pine forest, coastal and valley freshwater marsh, freshwater seep, southern coast-live-oak riparian forest, and mule-fat scrub. For the purposes of this document we will use the vegetation as described in, "A Flora of Santa Cruz Island" (Junak et al. 1995) which is based on the Philbrick and Haller (1977) and Holland (1986) classifications. There are 16 vegetation communities described under that Flora, southern beach and dune, valley and foothill grassland, coastal-bluff scrub, coastal-sage scrub, coyote-brush scrub, island chaparral, island woodland, southern coastal oak woodland, Bishop pine forest, intertidal and subtidal marine community, coastal marsh and estuary, freshwater seeps and springs, vernal ponds, riparian herbaceous vegetation, mule-fat scrub, and southern riparian woodland. Because some of these vegetation communities have been so altered, four additional types of vegetation will also be used to better clarify the current situation on SCI. These four additional vegetation communities are: cultivated, cypress grove, eucalyptus, and disturbed scrub savannah.

Coastal Bluff Scrub

This vegetation community is confined to the steep cliffs that surround much of Santa Cruz Island. Due to the inaccessibility of these bluffs this community has remained largely intact and unaffected by the grazing impacts felt on other parts of the island. This plant community has been called a refugium for some plant species. It is thought that many plant taxa now confined to these coastal bluffs will spread out into other areas of the island now that the sheep have been removed. On the north side of the island, plant taxa which are found in this community include: *Artemisia californica, Astragalus miguelensis, Achillea millefolium, Adiantum jordanii, Antirrhinum nutallianum, Coreopsis gigantea, Dudleya greenei, Eriogonum arborescens, Eriogonum grande var. grande, Erigeron glaucus*, and *Hazardia detonsa* among others. There are also two Federally listed as Endangered plant species, *Arabis hoffmannii* and *Malacothrix indecora*, which are confined to coastal bluff scrub. On the south side of the island, common coastal bluff species are similar to those on the north side but also include *Salvia mellifera, Encelia californica,* and *Mimulus longiflorus* as well as other plant taxa.

Grassland

This is a widespread plant community and may be the most dominant vegetation type on SCI. Introduced annual grasses are the most common types of plant species within this community, although patches of native perennial bunchgrasses - which are dominant in some areas - do occur. This community can be found on the coastal terraces and all slopes where heavy grazing has occurred. It is believed that the current extent of the annual grassland community has been created and artificially maintained by historic grazing practices and the feral herbivores on the island. Occasionally, solitary native shrubs such as lemonade berry *(Rhus integrifolia*), manzanita (*Arctostaphylos* sp.), and oaks (*Quercus* spp.) are found in the middle of these large annual grasslands indicating that native shrub communities may have previously existed there. With the removal of the feral sheep it is expected that these native shrubs will be begin to expand and change what is now

annual grassland back to other communities such as coastal sage scrub and island chaparral. The more prevalent exotic annual grasses include: *Bromus diandrus, Bromus hordeacous, Avena fatua, Avena barbata, Lolium multiflorum, Bromus madritensis*, and *Hordeum murinum*. Native forbs and perennial bunchgrasses also occur within this community and these species include: *Bloomeria crocea, Dichelostemma capitatum, Lasthenia californica, Layia platyglossa, Ranunculus californicus, Sisyrinchium bellum, Nassella pulchra, and Hordeum brachyantherum* ssp. *californicum.* Within this community, native plants such as *B.crocea* and *D. capitatum,* which store energy reserves in underground bulbs, tubers, or corms, are often the hardest hit by the feral island pigs.

Island Chaparral

Island chaparral is found throughout SCI primarily on the north-facing slopes. Although similar to chaparral found on the mainland, there are some differences both structurally and floristically. Structurally, the dominant island chaparral species are taller and more arborescent resulting in a more open woodland appearance. This may be due in part to climatic differences, a lower fire frequency, or the effects of long-term, intensive grazing. Floristically, island chaparral differs from mainland chaparral in that there is a heavy component of endemic manzanitas and oaks. Within the Central Valley and in Islay Canyon this community is dominated by chamise (*Adenostoma fasciculatum* var. *fasciculatum*), Santa Cruz Island manzanita (*Arctostaphylos insularis*), island ceanothus (*Ceanothus arboreus*), toyon (*Heteromeles arbutifolia*), and mountain mahogany (*Cercocarpus betuloides* var. *blancheae*). On the Monterey Shale bedrock of the isthmus, island chaparral is dominated by a prostrate variety of chamise (*Adenostoma fasciculatum* var. *prostratum*), McMinn's manzanita (*Arctostaphylos viridissima*), toyon (*Heteromeles arbutifolia*), and island oak (*Quercus pacifica*). Island oak can be the dominant plant species within this community and its dense, shrubby form and the abundant acorn production provides an almost perfect haven for the island feral pigs.

Coastal Sage Scrub

The coastal sage scrub community occurs on dry, rocky slopes throughout Santa Cruz Island. It is more common though on the south-facing slopes in the central and eastern portions of the Central Valley (Junak et al 1995). Although much of the coastal sage scrub community has been heavily disturbed, some intact areas do occur on the slopes east of Valley Anchorage. In these "intact" areas, nearly impenetrable thickets of shrubs approximately 3-4 ft tall are found. Dominant species within this community include: *Artemisia californica*, *Castilleja lanata* ssp. *hololeuca*, *Encelia californica*, *Eriogonum arborescens, Rhus integrifolia, Hazardia squarrosa, Opuntia littoralis*, and *Salvia mellifera*. Exotic annual grasses dominate the heavily disturbed areas of coastal sage scrub with occasional coastal sage scrub species scattered throughout. Coastal sage scrub intergrades with grasslands on gentle slopes with deeper soils and with island chaparral on north-facing slopes.

Southern Beach and Dune

Although steep coastal bluffs surround much of the perimeter of the island, a number of sandy beaches do occur especially on its south side. These sandy beaches for the most part are not large enough to form the typical southern dune scrub communities found on the mainland. Plant species found in these "limited" dune communities include sticky-sand verbena (*Abronia maritima*), silver beach-bur (*Ambrosia chamissonis*, sea rocket (*Cakile maritima*), beach evening-primrose (*Camissonia cheiranthifolia* ssp. *cheiranthifolia*), salt grass (*Distichlis spicata*), California saltbush (*Atriplex californica*), and Australian saltbush (*Atriplex semibaccata*). In the more stable dune

areas, the native plants: prostate coastal goldenbush (*Isocoma menziesii* var. *sedoides* and silver lupine (*Lupinus albifrons* ssp. *douglasii*) also occur.

Riparian

The riparian vegetation on SCI little resembles that found on the mainland. Riparian areas in general are the hardest hit vegetation community under intensive grazing regimes and the island riparian zones have been no exception. In many areas the native riparian plant species have been locally extirpated and non-native weedy plants and grasses occupy the riparian zone. Even prior to the introduction of alien herbivores, these areas were probably less diverse than comparable communities on the mainland. Mainland riparian dominants such as, white alder (*Alnus rhombifolia*), sycamore (*Plantanus racemosa*), and California bay (*Umbellularia californica*) do not occur on the islands (Junak et al, 1995). Where the island riparian vegetation still exists it can be divided into two components: herbaceous riparian vegetation and woodland riparian vegetation. Herbaceous riparian vegetation occurs in canyon bottoms where soil moisture is available for most of the year. The more common plant species in this community include: California maidenhair (*Adiantum jordanii*), *Agrostis viridis*, sticky baccharis (*Baccharis douglasi*), mule fat (*Baccharis salicifolia*), toad rush (*Juncus bufonius*), common monkey flower (Mimulus guttatus), and cattail (*Typha domingensis)*. Island riparian woodland can be found along permanent streams, especially on the north side between Cueva Valdez and Canada del Agua at the western end of the isthmus. Although heavily disturbed, Canada del Agua contains native riparian species such as big-leaf maple (*Acer macrophyllum*), stream orchid (*Epipactus gigantea*), and California bulrush (*Scirpus californicus*). On the south side of the island, riparian woodlands are found in Alamos Canyon and in the Coches Prietos drainage. Santa Cruz Island riparian zones are dominated by black cottonwood (*Populus balsamifera* ssp. *trichocarpa*), coast live oak (*Quercus agrifolia*), and willow (*Salix* spp.). The understory of this community is comprised of species found in the herbaceous riparian community as well as honeysuckle (*Lonciera hispidula* var. *vacillans*), blackberry (*Rubus ursinus*), and giant chain fern (*Woodwardia fimbriata*) in the wetter drainages.

Bishop pine woodland

Bishop pine which occurs on Santa Cruz and Santa Rosa islands is patchily distributed along the coast as far north as Humboldt County and down into Baja California. The phenology of this species can be highly variable and there is some controversy as to whether there is only one species, two species, or one species with two varieties or two forms. Some have proposed two varieties of Bishop pine, a northern variety, *Pinus muricata var. borealis*, and a southern variety, *P. muricata var. muricata*. Others have proposed that there are but two forms, *P. muricata forma muricata* and *P. muricata forma remorata*. Junak (1995) recognizes the two forms of *P. muricata*, *forma muricata* and *forma remorata*. Both these forms are present in the Bishop pine woodland on Santa Cruz Island. Large occurrences of Bishop pine are found on north-facing slopes in the upper reaches of Canada Christy, near Pelican Bay, and south of China Harbor. Smaller occurrences of Bishop pine are found in the upper portion of Canada de los Sauces, on Sierra Blanca ridge, and on the south side near China Harbor. Occasional over-story species mixed within the Bishop pine community include: island ironwood (*Lynothamnus floribundus ssp. Aspleniifolius)*, coast live oak (*Quercus agrifolia*), and island oak (*Q. tomentella*). Understory species include: chamise, coyote brush, globe lantern (*Calochortus albus*), toyon, mouse ears (*Hypochaeris glabra*), island deerweed (*Lotus dendroideus var. dendroideus*), island monkeyflower (*Mimulus flemingii*), chaparral current (*Ribes malvaceum var. malvaceum*), poison oak (*Toxicodendron diversilobum*), canyon

sunflower (*Venegasia carpesioides*), and the rare island barberry (*Berberis pinnata ssp. insularis*).

Island Woodland

This vegetation community can be found on SCI on the north-facing slopes, ravines, and canyons, particularly at the higher elevations (Cheatham and Haller, 1975, Philbrick and Haller 1977). Many of the dominant trees and shrubs in this community are endemic to one or more of the islands. Over-story species can vary from a mixture of island endemics to pure stands of oak (*Quercus* spp.) or ironwood (*Lyonothamnus floribundus*). Other dominant species include toyon (*Heteromeles arbutifolia*), and island cherry (*Prunus ilicifolia* ssp. *lyonii*). The oak species found in this community are canyon live oak (*Quercus chrysolepis*, Macdonald's oak (*Quercus macdonaldii*) and island oak (*Q. tomentella*). This community intergrades with island chaparral on dry, rocky slopes while turning into savannas on the deeper soils of the flats and more gentle slopes. The current extant of the savannas may be an artifact of the islands grazing history. Understory species include bent grass (*Agrostis pallens*), coyote-brush (*Baccharis pilularis*), Galium spp., manroot (*Marah macrocarpus*), island monkeyflower (*Mimulus flemingii*), lemonade berry (*Rhus integrifolia*), death camas (*Zigadenus fremontii*), and California polypody (*Polypodium californicum*).

Southern Coastal Oak Woodland

The dominant species within this community is coast live oak (*Q. agrifolia*) and it occurs on north-facing slopes and shaded canyons in the Central Valley and on the north side of the island. On the slopes, the more common understory species include toyon, wood mint (*Stachys bullata*), creeping snowberry (*Symphoricarpos mollis*), and poison oak (*Toxicodendron diversilobum*). In the canyon bottoms, common understory species include honeysuckle (*Lonicera hispidula* var. *vacillans*), manroot, blackberry (*Rubus ursinus*), milkmaids (*Cardamine californica* var. *californica*), and climbing penstemon (*Keckiella cordifolia*).

Coastal Marsh and Estuary

Coastal salt marshes are restricted to the upper intertidal zone of protected shallow bays, estuaries, and coastal lagoons (Barbour and Major 1977). Santa Cruz Island has small marshes or wetlands at the estuaries of several canyons including Prisoner's Harbor, Canada de los Sauces, Canada de Malva Real, and Scorpion Canyon. The physical condition of these marshes is dominated by the tides and the duration of tidal flooding. At times, the more shallow estuaries may undergo periodic closure - sometimes seasonal or longer - from the ocean inlets (Barbour and Major 1977). The dominant plant species at each of the marshes on SCI can be quite different but one species that seems to be present at all the sites is Distichilis spicata or saltgrass (Junak 1995). Other native species that can be found at one or more of the marshes include *Scirpus californicus, Typha domingensis, Salix lasiolepis, Baccharis douglasii, Baccharis salicifolia, Suaeda taxifolia, and Atriplex californica*. Introduced exotic species also occur at one or more of the marshes or wetlands. These include *Atriplex semibaccata, Cotula coronopifolia, Pennisetum clandestinum, Lythrum hysopifolium, Rumex crispus*, and *Hordeum murinum*. The feral sheep that once inhabited the island extensively used some of these marshes or wetlands. Since the removal of the sheep, vegetative cover, duration of flooding, and the depth of standing water has increased dramatically, especially in the estuaries on the south side of the island (Junak 1995).

Vernal Pools

Several vernal pools or ponds can be found scattered on Santa Cruz Island and more specifically at the western end of the isthmus near China Harbor. It is presumed that these vernal

pools once supported an assemblage of native flora but because of the intensive grazing history of the island most of the plant species that occur within these pools are weedy non-natives. Species identified by Junak occurring in the vernal ponds near China Harbor include: Australian saltbush (*Atriplex semibaccata*), bindweed (*Convolvulus arvensis*), short-podded mustard (*Hirschfeldia incana*), common plantain (*Plantago major*), curly dock (*Rumex cripus*), common sow thistle (*Sonchus oleraceus*), and annual exotic grasses.

Coyote-brush Scrub

This vegetation community is widespread on SCI at elevations below 500 ft. It is found primarily on moderate slopes and flats with loam to sandy clay loam soils (Clark et al, 1990). It intergrades with coastal sage scrub on rocky slopes. As with most of the vegetation communities on SCI, this shrubland has been heavily disturbed by grazing. Many species found in the community are weedy non-native plants, particularly the annual grasses. Typical alien plant species include wild oats (*Avena* spp.), rip-gut brome (*Bromus diandrus*), soft-chess (*Bromus hordeaceus*), and black mustard (*Brassica nigra*). Yellow starthistle (*Centaurea solstitialis*) and fennel (*Foeniculum vulgare*), both destructively invasive non-native plants, are found in coyote-brush scrub.

Threatened and Endangered Plant Species

Introduction

There are nine plant species federally listed as Threatened or Endangered on Santa Cruz Island: *Dudleya nesiotica, Malacothrix indecora, Malacothamnus fasciculatus ssp. nesioticus, Helianthemum greenei, Galium buxifolium, Thysanocarpus conchuliferus, Arabis hoffmannii, Malacothrix squalida, and Berberis pinnata var. insularis*. Each of these is variously threatened by the feral pigs on the island. The federal listing proposal for these species identified feral pigs as a major cause of decline for each of the plant species. The primary cause of impact to these rare species by feral pigs are rooting, direct feeding, and soil erosion.

Galium buxifolium

Galium buxifolium, or island bedstraw, is a small, woody shrub with separate male and female plants. Individuals can grow to a height of 4 ft. (1.2 m) with numerous branches. The leaves of this taxon are larger than those of most other species in the genus. This helps to distinguish it from the six other *Galium* species found on the Channel Islands.

Island bedstraw is known to occur on both Santa Cruz and San Miguel Islands. On Santa Cruz Island eight occurrences have been identified. In 1980, of these eight occurrences, two had populations of 50 plants or less and the remaining occurrences had less than six plants each (Hochberg et al 1980b). Two occurrences of *G. buxifolium* were discovered on San Miguel Island in 1993. One occurrence contained approximately 200 plants while the other occurrence contained fewer than 10 individuals. These two occurrences were re-located in 1998 and numbered 300 and 121 plants each. There are historical records of five additional occurrences on the island but no plants have been located at these sites for approximately 30 years.

Island bedstraw grows on bluffs and rocky slopes in coastal sage scrub and island pine forest. Associated species include California sagebrush (*Artemisia californica*), San Miguel Island locoweed (*Astragalus miguelensis*), giant coreopsis (*Coreopsis gigantea*), Greene's dudleya (*Dudleya greenei*), seaside daisy (*Erigeron glaucus*), and red buckwheat (*Eriogonum grande* ssp. *rubescens*). On the steep, rocky, cliffs other associated species include: yarrow (*Achillea millefolium*), San Miguel Island deerweed (Lotus *dendroideus* var. *veatchii*), cliff aster (*Malacothrix saxatilis* var. *implicata*),

wild cucumber (*Marah macrocarpa*), and lemonade berry (*Rhus integrifolia*).

Island bedstraw is threatened by soil loss and herbivory from feral pig rooting; and random (stochastic) extinction events due to its limited population size and range (USFWS 1999). The U.S. Fish and Wildlife Service (USFWS) listed this taxon as Endangered in 1997.

Helianthemum greenei

Helianthemum greenei, or island rush-rose, is a small shrub in the Cistaceae family. It can grow up to 18 inches tall and has alternate leaves covered with star-shaped hairs. It is distinguished from the common rush-rose (H. scoparium) by the dense reddish, glandular hairs that grow on the flower stalks. Island rush-rose was originally described by Robinson in 1895 and its type locality was a "dry summit near the central part of the island of Santa Cruz" (Abrams 1951).

Island rush-rose has been reported from four islands: San Miguel, Santa Rosa, Santa Cruz, and Santa Catalina. Both McMinn (1951) and Thorne (1967) reported seeing island rush-rose on San Miguel Island, but no collections from the island exist nor are there any known extant occurrences. On Santa Rosa Island, two collections were made from the 1930's but the plant had not been seen on the island since until April 1999 when two plants were found within a recently constructed elk and deer exclosure. Two extant occurrences of island rush-rose are also known from Santa Catalina Island (USFWS, 1999).

There are 14 occurrences of island rush-rose on Santa Cruz Island. In 1994 and 1995, surveys sponsored by the Biological Resources Division of the USGS (re)-located all of those occurrences, ten of which had a mean number of nine plants. The remaining 4 occurrences ranged between 500 – 1,000 individuals with a mean number of 663 (McEachern and Wilken, 1996). It was subsequently determined the number of individuals in the latter occurrences was related to recent fires that had occurred on the island. This observation of increased numbers after fires suggests the species is a "fire follower" and that an integral part of its life history is spent as seed stored in the soil between fire episodes. Island rush-rose grows in open, exposed areas in chaparral, coastal sage scrub, and island pine forest.

Island rush-rose is vulnerable to soil loss and rooting by feral pigs (USFWS 1999). This species was listed as Threatened by the USFWS in 1997.

Dudleya nesiotica

Dudleya nesiotica, or Santa Cruz Island live-forever, was first collected from the west end of Santa Cruz Island in 1950. It is a succulent perennial in the stonecrop family. This plant has a short, thick, underground stem that is topped at the soil surface with 8-16 narrow leaves in a basal rosette. From this basal rosette, several flowering stems will arise.

Santa Cruz Island dudleya is only known to occur at Fraser Point on the west end of Santa Cruz Island. Within this general area, the plant occupies approximately 32 acres. From 1994-1996, estimates of the population ranged from 30,000 to 60,000 individuals.

Santa Cruz Island dudleya appears confined to the lower marine terraces in coastal scrub and grasslands. Associated species at the western end of the occurrence include, California saltbush (*Atriplex californica*), crystalline iceplant (*Mesembryanthemum nodiflorum*, alkali heath (*Frankenia salina*, goldfields (*Lasthenia californica*), and pickleweed (*Salicornia subterminalis*). The eastern end of the occurrence is associated with Australian saltbush (*Atriplex semibaccata*), soft-chess (*Bromus hordeaceus*), goldfields, purple needlegrass (*Nasella pulchra*), and vulpia (*Vulpia myuros*).

Although Santa Cruz Island dudleya is a perennial, its leaves die back to the ground every year during the dry late summer and fall months.

The underground corm takes several years to develop. This species is vulnerable to competition from non-native grasses, soil erosion, herbivory by feral pigs, and disturbance by pig rooting. Due to its limited range, this species is also threatened by random (stochastic) extinction events (USFWS 1999). In 1997, this species was listed as Threatened by the USFWS.

Arabis hoffmannii

Arabis hoffmannii, or Hoffmann's rock-cress, was first collected from the coastal bluffs east of Platts Harbor on Santa Cruz Island. Hoffmann's rock-cress, a member of the mustard family, is a slender herb that lives for several years, flowers and then dies. This plant can grow to approximately 2 feet high and has one to several stems. This species was originally reported from three of the northern Channel Islands, Anacapa Island, Santa Cruz Island, and Santa Rosa Island. Surveys conducted in the early 1990's though failed to re-locate the one reported occurrence on Anacapa Island. The original occurrence on Santa Rosa Island has also disappeared but in 1996 a new location in middle Lobo Canyon was discovered. This new occurrence consisted of eight plants, three of which were flowering. Unfortunately no plants were observed at this location in 1998. There are three known extant occurrences for Hoffmann's rock-cress on Santa Cruz Island. The occurrence near Platts Harbor is located on rocky volcanic cliffs. Only a few dozen plants have been directly observed at this location. Another occurrence is found near Centinela Grade. When this occurrence was re-located in 1990, approximately 30 individuals were noted to exist at the site. Since that time, annual monitoring has found fewer than 30 plants and the very steep rocky site has been repeatedly rooted by pigs.

Ex situ monitoring (Wilken 1996) has shown that individual plants can reproduce within two years following establishment. Individual rosettes of the species are monocarpic, flowering once before dying, however some plants have more than one rosette of leaves. Pollinators do not appear to be necessary for seed set and individual plants can produce between 3,000 – 4,000 seeds. However, monitoring at two of the SCI sites indicates that successful establishment of new plants is low. This is thought to be due to a lack of favorable seed germination sites, a high rate of seedling mortality, or a combination of both factors (Wilken 1996).

Arabis hoffmannii was listed as Endangered by the USFWS in 1997. Identified threats to this species include soil erosion, loss of shrub canopy cover, trampling and predation caused by feral pig rooting, and competition with non-native annual plants. This taxon is also threatened by stochastic extinction events because of its extremely limited distribution and population size (USFWS 1999).

Berberis pinnata ssp. insularis

Island barberry was first collected from Santa Cruz Island, west of Centinela Grade in 1932. It is a perennial shrub with spreading stems, which can reach 25 feet high. The leaves are large and are divided into 5 – 9 shiny leaflets. The flowers are yellow and develop in clusters at the branch tips.

Island barberry was originally reported from three of the northern Channel Islands, Anacapa Island, Santa Rosa Island, and Santa Cruz Island. On Santa Cruz Island, there are three known occurrences. One occurrence is found on the north slope of Diablo Peak. In 1994 it consisted of 24 large stems and 75 small stems. These numbers may represent one to several clonal individuals. The second occurrence is near Campo Raton. In 1979, there was estimated to be fewer than 10 individuals but a recent survey was only able to find two plants. Both of these were reported by Wilken to be in danger of being uprooted from erosion (USFWS 1999). The third occurrence, at Hazard's Canyon, was reported by Junak to consist of approximately 20 stems, which may all be clonal (USFWS 1999). Both Santa Rosa Island and Anacapa Island were reported to have one known

occurrence of island barberry. Both of these occurrences are now thought to be extirpated.

Identified threats to island barberry include soil erosion and habitat alteration caused by feral pig rooting, lack of successful sexual reproduction, and extinction from random disturbance events (USFWS 1999). This species was listed as Endangered by the USFWS in 1997.

Malacothamnus fasciculatus var. nesioticus

M. fasciculatus var. nesioticus, or Santa Cruz Island bushmallow, was first collected from Santa Cruz Island in 1886 and is endemic to that island. It is a small semi-woody shrub in the mallow family. This species can grow up to 6 feet tall, and has slender branches covered with star-shaped hairs. The leaves are bi-colored, dark green on the upper surface and gray on the lower surface. The flowers are rose colored and are scattered along the ends of the branches.

Currently there are three known occurrences of Santa Cruz Island bushmallow and all are found within chaparral and the remnant coastal sage communities. The number of individuals found within the three occurrences ranges from 19 to 60 plants. However, like island barberry, this species can reproduce asexually and the number of plants counted represent clones from only 3 – 10 genetic individuals. Cuttings grown at the Santa Barbara Botanic Garden have produced hundreds of flowers but have yielded only two to three seeds per plant. On Santa Cruz Island, associated plant species include California sagebrush (*Artemisia californica*), Santa Cruz Island buckwheat (Eriogonum arborescens), toyon (*Heteromeles arbutifolia*), and lemonade berry (*Rhus integrifolia*).

Threats to Santa Cruz Island bushmallow include soil erosion and habitat alteration from feral pig rooting, and extinction from random disturbance events (USFWS 1999). This species was listed as Endangered by the USFWS in 1997.

Malacothrix indecora

Malacothrix indecora, or Santa Cruz Island malacothrix, is a mat-like herb in the sunflower family. The stems grow up to 4 inches tall and are surrounded by numerous fleshy leaves. The flowers are small and are yellowish-green in color.

Santa Cruz Island malacothrix is known to occur on three islands, San Miguel Island, Santa Rosa Island, and Santa Cruz Island. This species was originally collected from Santa Cruz Island in 1886 by Greene. It occurs along the edge of vegetated habitat along coastal bluffs and is often associated with midden soils. Because it is an annual species, the number of individuals can vary widely within an occurrence from year to year. On Santa Cruz Island, near Black Point, an occurrence discovered in 1980 by Steve Junak was observed to have several hundred plants in 1985. In 1989, however, this same occurrence was found to contain only 50 plants. Historically, there have been 2 – 3 occurrences recorded from Santa Cruz Island but these are thought to have been extirpated. Presently only one occurrence is known to exist on Santa Cruz Island, near Black Point.

Identified threats to Santa Cruz Island malacothrix include soil erosion and habitat alteration from feral pig rooting, herbivory by feral pigs, trampling by hikers, seabird nesting activity, and extinction from random disturbance events (USFWS 1999). This species was listed as Endangered by the USFWS in 1997.

Malacothrix squalida

Malacothrix squalida, or island malacothrix, was first collected from Santa Cruz Island by Greene in 1886, near Prisoners Harbor. A second collection was made on Santa Cruz Island in 1968, near Potato Harbor. To date the latter occurrence is the only one known to be extant on Santa Cruz Island. However, the plant was also later discovered growing on Middle Anacapa Island in 1963. Additional surveys observed the plant to be

confined to several small colonies on top of coastal bluffs at the east-end of Middle Anacapa Island.

Island malacothrix is a small annual plant in the sunflower family. It grows to a height of approximately 12 inches and has basal leaves that can reach 6 inches in length. The flowers are light yellow and are cluster in small hemispheric heads. Through cultivation, it is known that this plant is self-pollinating and self-compatible.

Identified threats to *M. squalida* include soil erosion and habitat alteration from feral pig rooting, seabird nesting, and extinction from random disturbance events (USFWS 1999). This plant was listed as Endangered by the USFWS in 1997.

Thysanocarpus conchuliferus

Thysanocarpus conchuliferus, or Santa Cruz Island fringepod, was first collected from Santa Cruz Island in 1886 by Greene and Brandegee. A search of herbarium records identified 14 occurrences on the island. Surveys in 1980 were able to only re-locate 8 of those historical locations. Today the only current extant population is at Puertozuelo, consisting of only a few individuals. This species is endemic to Santa Cruz Island.

Santa Cruz Island fringepod is a small annual in the mustard family, growing to a height of only 5 inches. There are one to several stems per plant which terminate in a cluster of small pink to lavender flowers. Little is known about this species other than it blooms from March through April and that only one seed is produced per flower.

Identified threats to Santa Cruz Island fringepod are predation, soil erosion, and habitat alteration from feral pig rooting. This species is also threatened with extinction from random disturbance events. In 1997, this plant was listed as Endangered by the USFWS.

Non-Native Vegetation

Introduction

The oldest evidence of human occupation on Santa Cruz Island is 8900 BP, though evidence from Santa Rosa and San Miguel Islands indicate human presence there are early as 10000 years BP. The interactions of indigenous peoples with island vegetation included harvesting, habitat disturbance and directed, as well as accidental plant dispersal. They likely made large modifications to the landscape that influenced today's vegetation patterns, by burning, clearing, and cultivation.

The last 150 years have seen an enormous change in the vegetation of the island, in a very short period of time. The most significant factors have been the introduction and proliferation of feral sheep and pigs, removal of native vegetation cover by these animals, and by the associated ranching and farming activities, and the arrival and spread of aggressive non-native plants.

Extremely high erosion rates have been documented, especially between 1874 and 1920, associated with the introduction of large, non-native grazing animals, particularly sheep. As evidenced by pollen records constructed for nearby Santa Rosa Islands (Cole, 1994), alien plants were arriving and spreading rapidly; presumably they were spreading similarly on Santa Cruz Island, which underwent the same agriculture-related impacts.

Feral pigs have also adversely affected plant communities, especially by trampling and rooting under oak woodland and chaparral canopies. Pig activities have inhibited regeneration of native trees and shrubs, caused destruction of litter and promoted accelerated erosion. The soil disturbance they cause, and the seeds they transport, have facilitated establishment of non-native plants within these communities.

Vulnerability of Islands

Islands and remote peninsulas seem consistently vulnerable to invasion by non-native plants. This may be because they have relatively low numbers of native species, or are missing certain distinctive plant groups, leaving "empty niches" that new arrivals can exploit. It may also be due to having no large native herbivores, so that native plants did not evolve the classic defense mechanisms such as spines, small hard leaves, or foul-tasting chemicals that would have made them unpalatable to the pigs, cattle, sheep and other grazers brought by humans. (Randall 1996)

Current situation on Santa Cruz Island

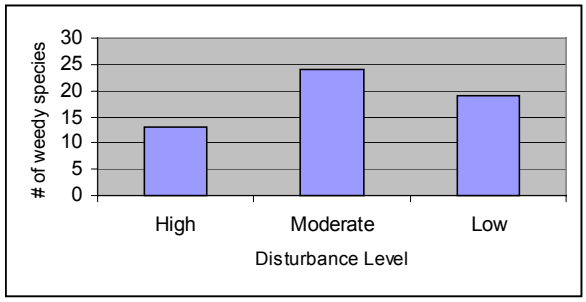
Santa Cruz Island today has a total of 650 plant taxa; at least 170 of these are introduced. This constitutes about 26% of island's total flora. This figure is at about the median point of the ranges of the proportion of non-native/total flora--20% to 47%--of all the eight California Channel Islands, is slightly lower than the average rate for the northern islands, and is notably lower than the average for the southern islands. Eleven of Santa Cruz Island's 88 plant families and 82 of its 348 plant genera are represented exclusively by non-native taxa.

Santa Cruz Island is subject to the continual risk of colonization and re-colonization by non-native plants, because of transport of materials and vehicles to the island, travel to the island by residents and visitors, and natural processes of transport of seeds of non-native plants from the mainland to the islands. Non-native plants tend to be able to capitalize on disturbance to native vegetation, such as fire or grazing animals, to gain a foothold in a new area. Santa Cruz Island is particularly vulnerable to this because of the lack of adaptation by native plants to herbivory

In general, worldwide, it has been observed that many decades often pass between the first introduction of a plant and its eventual rapid spread. It is presumed that during this period, seedbanks are developing, seeds are being dispersed, and the species is adapting to local conditions. Many of the species of non-native plants that occur on Santa Cruz Island, as well as on the California mainland, appear to be approaching the end of this 'lag phase', as evidenced by increasing abundances, ranges, and types of habitats invaded, and in the rate of increase of these attributes. Notable among these plants are smilo grass, fennel, and tree tobacco. We expect that many of the island's alien species are poised for this rapid expansion phase, making it even more critical to limit the disturbances that facilitate weed spread.

Alien plants of Santa Cruz Island, like any land management area, can be organized into functional groups, related by elements of their life histories such as physical stature, structure, seed longevity, dispersal mechanisms, type and amount of storage tissues, their relationships to current and previous land uses and past and ongoing disturbances. Distributions and abundance of at least 56 of the approximately 170 alien plants occurring on SCI are particularly dependent on the disturbance caused by the island's feral pigs (Table 6). Some of the factors considered for dependence on disturbance are life history of the species, its individual size and structure, and the species' population patterns and persistence, seed longevity and dormancy mechanisms, and seedbank capability.

Figure 4. Weed species correlated to disturbance level



Fennel

History

Foeniculum vulgare Mill. (fennel) was present in California for over 100 years before it became an aggressive invader (Greene 1887, Jepson 1925, Hickman 1993). Within the last ten years fennel has successfully invaded grassland and coastal sage communities throughout California, displacing the native flora and reducing biodiversity by producing thick monospecific stands (Beatty 1991, Beatty and Licari 1992). In 1996 *Foeniculum vulgare* was placed on the CALEPPC (California Exotic Plant Pest Council) list of California's exotic plant species of greatest ecological concern (Anderson et al. 1996).

Fennel was introduced on Santa Cruz Island in the late 1800's (Greene 1887). Vectors for fennel dispersal during 19th and most of the 20th centuries were likely in the hoofs, fur and feces of cattle (*Bos taurus*) and feral sheep (*Ovis aries*), and along roadside passages (Beatty and Licari 1992, Brenton and Klinger *in press*). Although the grazers dispersed fennel, they also controlled fennel by consuming the plants that germinated and grew in the grasslands and disturbed communities (Brenton and Klinger 1994).

The removal of cattle and feral sheep from The Nature Conservancy portion of the island in the 1980's left Santa Cruz Island with a highly disturbed and vegetation free landscape- the perfect landscape for fennel invasion. *Foeniculum vulgare* was able to take advantage of this open disturbed space. With the end of a 4-year drought following the removal of grazers, prolific fennel growth occurred across Santa Cruz Island. Fennel spread throughout the Central Valley and into the upper grasslands and coastal sage communities displacing native species (Crooks and Soulé 1999). Fennel's ability to grow and reproduce during the hot and dry Mediterranean summers also increased the spread of fennel (Brenton and Klinger 1994). Fennel spread in many of the previous pasture areas and has spread via roadways and feral pigs throughout Santa Cruz Island producing monoculture thickets with over 90% cover (Klinger 1998, Erskine unpublished data). Currently, a large scale, model fennel management program is underway in Santa Cruz Island's Central Valley. The fennel management proposal for the isthmus of Santa Cruz Island follows the Central Valley management protocol.

Biology

Fennel (*Foeniculum vulgare*) is a perennial herb that can grow 1-3m tall. It is a dicot species in Family Apiaceae, the carrot or parsley family. Economic Apiaceae plants include, among others, dill (*Anethum*), celery (*Apium*), and English-ivy (*Hedra*). Other weedy species in the Apiaceae family, originally introduced as cultivated species include wild caraway (*Carum carvi*), and wild carrot (*Daucus carota*). Two well-known toxic weeds in Family Apiaceae are western water hemlock (*Cicuta douglasii*) and poison hemlock (*Conium maculatum*) (Whitson et. al. 1996, Zomlefer 1994).

Fennel produces a taproot that can range from 0.9-3m in length. It is native to southern Europe, escaped from cultivation in California, and is now a widespread weed. The photosynthetic stems are erect and branched with multiples stems produced from a single crown. The stems are pithy and become hollow as the season progresses.

Fennel reproduces sexually and is a primarily outcrossing species. Pollination occurs predominately via insects. Flower production begins as early as late May and continues through October (Erskine personal observation). Wind is not considered an important pollination device. Flowers are strongly protandrous, and bloom initially in the primary umbels, followed by secondary, then tertiary umbels (Koul *et. al.* 1993). Umbels are large and conspicuous to facilitate insect attraction. Sepals are absent and petals are yellow. Common pollinators of fennel include

flies, bees, wasps and beetles. Tens of thousands of seeds can be produced on an individual fennel plant. The two seeds produced per ovary often fall together as one schizocarp (Munz 1986, Zomlefer 1994). Seed dispersal occurs when schizocarps fall off maternal plants to the ground, via water in riparian communities, via animals, and anthropogenically (vehicles, shoes, machinery). Some seeds can remain within the umbel over winter, and these seeds are viable the next spring.

Anecdotal evidence suggests a long-lasting seedbank (5-7 years of viability) for fennel, yet there is no quantitative evidence of such a seedbank. Seeds do not require a chilling period or any type of scarification to germinate, although they do appear to need light for germination and growth. Optimal germination temperature ranges between 20ºC and 23ºC and germination primarily occurs within 5-7 days at these temperatures (Erskine unpublished data). With this fast germination time, fennel is able to germinate in early spring and throughout the spring (if rains continue) on Santa Cruz Island. Germination rate after one year of cold storage ranged from 60-85%, at temperatures between 16ºC and 25ºC. (A large portion of the seeds that did not germinate in this study were killed by fungi (Erskine unpublished data)). If the cold storage results are applicable to the field, these results indicate that those seeds that do not germinate the first year from the seedbank have a high probability of germinating the second year, even if the mother plants are removed. For this reason, a single year of treatment would never eradicate fennel.

Fennel possesses many phenotypic traits characteristic of weedy species: rapid growth rate, large seed rain, few germination requirements and short juvenile period (Baker 1965, Erskine personal observation). Fennel also has the ability to reproduce asexually from the crown of the root system. Fennel possesses biological characteristics that make it a good invader in California, and particularly on Santa Cruz Island. Fennel produces a large taproot to obtain water during the dry Mediterranean summers, when most other herbaceous species have set seed. By late June, flower production is in progress, and leaves begin to fall off of the stems. Photosynthesis continues through the green, stomatic stems. Erect stems receive less direct light and transpire less than leaves, and therefore decrease summer stress such as high temperautres and water loss, to the plants.

Fennel is known to invade grasslands, coastal sage scrub, savannas, riparian communities, roadsides and most other disturbed communities, all found on Santa Cruz Island. Fennel has the ability to tolerate pH's ranging from 4.8-8.3, precipitation between 30cm and 260cm annually, and temperatures between 0ºC and 27ºC (Simon 1984, Erskine personal observation). Fennel proliferates on well-drained loamy soils (Colvin and Gliessman 2000), but can also invade extremely eroded soils, cliff edges and south-facing slopes (Erskine personal observation). The ability to invade a wide variety of communities, and to tolerate extreme heat and freezing conditions, has allowed fennel to invade many plant communities on Santa Cruz Island. The only communities fennel has not invaded on Santa Cruz Island are those communities with heavy cover.

Fennel appears to need sunlight to grow, and the seeds cannot germinate in communities with thick canopies. Although fennel seedlings can be found below fennel plants and within Mediterranean annual grass communities, these communities are usually patchy. Fennel seedlings are not generally found in such closed canopy communities as chaparral, oak woodlands and pine stands without large-scale disturbance (i.e. pig rooting or burning).

Disturbance and Fennel

Fire removes above ground plant biomass producing open space and canopy gaps for fennel seeds to germinate. Fire alone appears to promote fennel invasion, but there are no quantifying data to suggest a mechanism for this improved invasion ability other than the increase in photon flux density that fennel seeds receive. In areas of high pig

density, and large pig rooting zones, fennel seedlings can be seen, as well as newly established adult fennel plants. As with fire, the anthropogenic and pig caused disturbances allow fennel seeds to receive more light, and therefore to germinate and thrive. Feral pigs, vehicles, humans, and machinery are vectors for fennel invasion through the disturbances they cause, and the transport of seeds.

Fennel covers over 10% of Santa Cruz Island (Klinger unpublished data), and is currently spreading along roadsides into many coastal sage, grassland and bare/disturbed sites. Although there appears to be distinctly separate large stands of fennel across the island, roads and pig trails are obvious corridors of invasion connecting these fennel populations. Eradicating feral pigs from Santa Cruz Island will remove the vector for dispersal and establishment, and this will, in turn, facilitate fennel control throughout the island.

Cultural Resources

Historical Overview

Largest of the Channel Islands and containing a varied and complex series of plant communities, Santa Cruz Island seems to have supported a large human population during most of prehistory. Eleven historic villages are known for Santa Cruz Island, equal to the total number recognized for both Santa Rosa and San Miguel Islands. Earlier sites, ranging in size from only a few meters square to extensive shell mounds covering hundreds of square meters are found along the coastline and within the interior at advantageous locations. Some of these mounds contain distinctive layers of red abalone shell, indicative of occupation about 5000 to 8000 years ago. In addition to shell mounds, prehistoric sites include chert quarries and workshop sites, rock shelters, and rock pavements ethnographically identified as shrines. Some of the rock shelters contain rock art of a simple style quite distinct from that known on the mainland. Formal cemeteries are found close to many villages, especially later sites, and isolated, seemingly random, human burials are recorded for the island as well. The potential number of burials ranges into the tens of thousands.

This rich complex of sites constitutes the remains of more than 8000 years of occupation, development, and flowering of the group known as the Chumash, the inhabitants of the northern Channel Islands and the Southern California area from San Luis Obispo to Malibu. Recent research shows occupation 8900 years ago, and the potential for even older material exists on the island. Like Santa Rosa and San Miguel Islands, deposits on the west end containing pygmy mammoth remains could also contain evidence of older human occupation.

Although Chumash occupation of Santa Cruz Island ended in the early nineteenth century, many individuals who trace their ancestry to specific villages retain a lively interest in the preservation and management of their heritage. Between three and ten thousand Chumash live in California today.

The European presence in the Channel Islands began with Juan Rodriguez Cabrillo's explorations in 1542, followed by the subsequent expeditions of Sebastian Vizcaino in 1602 and George Vancouver in 1769. While sea otter hunters, smugglers, and others visited the islands and left their traces during the historic period, permanent European settlement did not occur on the islands until the mid-1800s.

The Chumash population left Santa Cruz Island by the 1830s, settling primarily in and around the Spanish Missions in Santa Barbara and San Buenaventura. In 1839, the Mexican government granted title to the island to Andres Castillero, who became the first private owner of Santa Cruz Island. In 1853, Dr. James Barron Shaw, acting as agent for Castillero and the island's subsequent owners, the Barron and Forbes Company, began stocking the island with sheep, horses, cattle and hogs. Shaw

managed the island rancho until 1869, developing several ranch outposts and the infrastructure that linked them. In 1869 ten San Francisco investors purchased the island and formed the Santa Cruz Island Company. Justinian Caire, a Frenchman and one of the ten investors, acquired the majority of the shares in the Santa Cruz Island Company during an economic downturn in the 1870s and became sole owner of the island by the end of the 1880s or early 1890s. Caire and his descendants continued and expanded the sheep ranching and agricultural enterprises on the island.

The heart of Shaw's and, later, Caire's operation was located in the island's central valley. The main ranch included a residence, bunkhouses for winemakers, shepherds and vaqueros, barns, winery buildings, a dining hall, bakery, laundry, kitchen, shops for wagon makers, blacksmiths and tool and saddle makers, and a chapel. Substantial acreage was planted in grapevines, hay and fruit trees.

Caire's island workforce consisted primarily of French, Italian, Hispanic and Native American workers, reflecting Caire's French origins, his wife's Italian heritage, and the local population. The island operation was a largely self-sustaining community that supported a diversity of permanent and seasonal employees, which included a blacksmith, carpenters, painters, team drivers, dairymen, cooks, stone cutters and masons, gardeners, dairymen, vintners, grape pickers, sheep shearers, wagon and saddle makers, a cobbler, a butcher, a baker, and a sea captain and sailors.

The island ranching system developed by Shaw included the main ranch and satellite ranches at the east and west ends of the island and at La Playa (Prisoners' Harbor). Caire continued to use these ranches and established additional ranches and camps at other locations on the island. The main ranch and the outranches at Scorpion, Prisoners' and Christy remained the primary ranches through the Justinian Caire period. The island's sheep population reached 40,000-50,000 head under Caire, their wool and meat being shipped to market from Scorpion Ranch and Prisoners' Harbor. When Caire died in 1897, an unequal distribution of his estate among his heirs led to a prolonged period of litigation. Ultimately, the dispute was settled by a court-ordered partition of the island in 1925, which divided the island into parcels with the western 90 percent (54,500 acres) of the island going to Caire's widow and four of their children, and the eastern 10 percent (6,000 acres) going to the two married Caire daughters. The Caire family maintained the western portion of the island until 1937, when they sold their land to Los Angeles businessman Edwin L. Stanton. Stanton attempted unsuccessfully to revive the island's sheep business that had declined dramatically after Justinian Caire's death, and then switched to cattle ranching. Edwin Stanton's son and heir, Carey Stanton, continued the cattle ranching operations after his father's death in 1963. In 1978, the Nature Conservancy secured permanent protection of the property from Stanton, and full control of the property upon Stanton's death, which was in 1987.

The east end of the island remained in the hands of the Caire descendants, consolidated under the ownership of Ambrose and Maria Gherini. They continued the sheep ranching operation, with headquarters at Scorpion Ranch and Smuggler's Cove, the two east end satellite ranches. The ranch operations were overseen by a series of superintendents and caretakers until the island was converted to a private hunting, camping and recreational venture in the early 1980s. The National Park Service acquired full ownership of the east end of the island in 1997.

Cultural Resources

Santa Cruz Island contains thousands of relatively intact archeological sites filled with rich research opportunities, especially investigations into human adaptation and development in a context of changing environments and cultural conditions.

More than 630 archeological sites have been recorded on Santa Cruz Island with intensive survey

covering perhaps 20% of the island. The entire island probably contains about 3000 archeological sites.

Sites on Santa Cruz Island are receiving increasing attention from archeologists because of the relatively long and undisturbed record remaining on the island. Santa Cruz Island archeological sites remain relatively undisturbed because of the lack of intensive development and the absence of burrowing animals, such as gophers and squirrels, on the island. In contrast to the mainland, where development and burrowing have seriously impacted our ability to understand the Chumash past, the sites on the island and their relatively natural context constitute the best materials for understanding the past of the Chumash, although feral pigs and their destructive rooting threaten to destroy the record of this rich past.

The island's archeological resources were listed on the National Register in 1978 as the Santa Cruz Island Archeological District. The district encompasses only the western 90 percent of the island because of the division of ownership at the time of nomination and listing. The previous owners of East Santa Cruz Island did not choose to include their holdings within the District. There is no question that the archeology of the eastern portion of the island is at least as significant as the present archeological district, particularly since it contains most of the chert quarries exploited in the past. The National Park Service is managing the archeological resources on the east end of the island as a property eligible for the National Register until such time as the existing nomination can be amended to add the east end acreage and resources.

In addition to the Chumash record, there is extensive historic archeology centered on the island locations where ranches developed, as well as on the numerous coastal fishing and recreational camps, which flourished around the turn of the 20th century. There are remnants of oil exploration on the island, at least one abandoned World War II military encampment, and the remains of shipwrecks can be found on the beaches and intertidal zone and in the waters surrounding the island.

The ranching and agricultural resources form a historic period cultural landscape over much of the island. The main ranch in the Central Valley is the largest and most significant of the ranch complexes. Most of the earliest buildings constructed under Shaw's superintendence were of adobe or wood, and most have disappeared. During the Caire era, much of the permanent construction was of stone masonry or brick. The design of the buildings with their whitewashed stucco surfaces, large corner quoins and cobble walkways exhibit the Mediterranean heritage of their owners. All of the construction materials except lumber were gleaned from the island; brick was produced in on-island kilns. Corrals and fencelines define the ranching-era work areas, fields and pastures. Furrow lines from the grapevine plantings can still be seen on many of the slopes that were cultivated for wine production.

In addition to the main ranch, significant building complexes remain at Prisoners' Harbor, Scorpion Ranch, Smuggler's Cove and Christy Ranch. Although all of these ranches except Smuggler's Cove were established during Shaw's management of the island, most of the remaining buildings date to the Caire period. The design and construction of the primary buildings on the outranches are similar to that of the main ranch, though they contain fewer buildings and landscape features.

Ranches and outposts once stood at Rancho Punta West, Rancho Nuevo, Buena Vista, Portezuela and Rancho Sur. Their locations are marked now by foundations, plantings and remnants of structures. Stone foundations of barns are found in a number of locations on the east end. A Stanton-period ranch was built at Del Norte in 1952-53. Its frame house and corrals have been maintained by the Santa Cruz Island Foundation.

Most of the island's road system dates to the Caire development period, although the Ridge Road

or "Camino Viejo" predated Caire. The central valley roads lined with eucalyptus trees form grand avenues near the main ranch. The Scorpion Valley road supported by an immense dry stone retaining wall illustrates the challenges that the nineteenth-century ranchers faced in developing this difficult terrain. The Stanton family developed many dirt ranch roads in the 1940s through 1960s, especially on the isthmus, and the Navy improved the road from Prisoners' Harbor to the Navy base in 1950.

Dry stone structures, built in the late 1800s by Italian masons and laborers, are found throughout the island. Structures include stone-lined wells, rock retaining walls along stream channels and roads, and more than 200 check dams on the east end alone, built to channel water and slow erosion. Large rock piles dot the east end of the island, created when the fields were cleared for cultivation.

Plantings of eucalyptus, cypress, pepper trees and other ornamental species are found at the ranch sites and elsewhere on the island, dating primarily to the Caire era. A large olive grove survives at Smuggler's Cove. Orchards and plantings of fruit and nut species are located at the main ranch and many of the outranches. A few rare examples of grape plantings remain in the Central Valley.

Fencelines throughout the island delineate pastures. Remnants of the sheep ranching operations include corrals, watering troughs and other features. While the nineteenth-century fencelines and features on the eastern end of the island remain relatively unchanged since their construction, the ones on the western part of the island were altered about 50 years ago to accommodate Stanton's cattle operations.

The ranch complexes and cultural landscape features are significant under several National Register criteria although they have not yet been nominated to the National Register of Historic Places. The long period of ranching and agricultural development has resulted in a pastoral landscape that reflects the island's management by Shaw, Caire and Stanton and which retains a great deal of historic integrity. The island itself may be considered a significant rural historic landscape, or a series of individual historic landscapes.

Human Uses and Values

Socioeconomic

Although all of Santa Cruz Island is within the boundaries of Channel Islands National Park, The Nature Conservancy owns the bulk of Santa Cruz Island. The National Park Service currently owns the eastern 24% of the island, while TNC owns the remaining 76%. In August of 2000 TNC completed a gift of 8,500 acres of property to NPS, increasing NPS holdings from 10% to 24%. The conveyance includes lands on the isthmus of Santa Cruz Island. The gift will allow NPS and visitors better access to SCI via Prisoners' Harbor, and is intended to facilitate cooperation between NPS and TNC.

Use of the island is very different on lands owned by NPS and lands owned by TNC. In general, Santa Cruz Island lands owned by NPS are fully open to visitor access and use, whereas some lands owned by TNC are available for restricted use by the public. Eastern Santa Cruz Island has been fully open to visitor use since 1997, and has become the most popular visitor destination in the park. The number of visitors to East Santa Cruz Island has increased since the Park completed acquisition of the east end in 1997. The Island Packers Company, as concessionaire, provides boat transportation to Santa Cruz Island, landing visitors at Scorpion Bay on a nearly daily basis. It also provides scheduled trips to several parts of TNC's lands. A campground has been established at Scorpion and is very popular, with use heaviest on weekends and filled to capacity on holiday weekends. Visitor activities on east Santa Cruz include hiking, beach-going, kayaking, and snorkeling. Private boaters also visit east Santa Cruz Island. A popular hike is across east Santa

Table 5. Number of visitors on East Santa Cruz Island, 1996-1999.

	1996	1997	1998	1999
Recreational Day visitors on boats	19,870	63,851	50,020	55,818
Recreational Visitors ashore	8,423	13,581	16,395	18,236
Recreational Overnight visitors on boats	8,006	13,471	14,543	12,971
Campers	1,990	5,675	7,413	15,442
TOTAL	40,285	98,575	90,369	102,467

Cruz from Scorpion to Smuggler's Harbor and return. Currently there is no backcountry camping on Santa Cruz Island.

The conveyance of lands on the isthmus to NPS will bring about changes in land use on that portion (8,500 acres) of the island. Prisoners' Harbor will become the main access point for visitors to the isthmus. The dock at Prisoner's Harbor is currently in disrepair and cannot be used. The NPS will repair the dock in late 2000. Visitor services on the isthmus will be limited at first. Full development of visitor services would not be implemented until a planning effort is completed. Until that time, visitor services will likely be limited to restroom facilities at Prisoners' Harbor, and establishment of a small backcountry campground near Del Norte. The latter facility will allow backpackers to hike from Prisoners' Harbor across High Mount to Scorpion Bay.

The other visitor activity currently available for visitors to the isthmus is a reservations-only hike to Pelican Bay. The Bay is accessible only via TNC-owned lands, and will remains so now that the land conveyance is complete. TNC currently allows Island Packers Company to lead visitors on organized hikes to Pelican Bay and return. Additionally, TNC operates a landing permit program that allows private boaters to land at any of the anchorages and day hike in the vicinity.

Scientific research is a primary use of TNC lands on Santa Cruz Island. The University of California has operated a field station on Santa Cruz Island since 1966. Santa Cruz Island Reserve is part of the University of California Natural Reserve System. Many researchers carry out projects on Santa Cruz Island through the UC Reserve annually.

Santa Cruz Island Primary Restoration Plan

CHAPTER FOUR
ENVIRONMENTAL EFFECTS

Introduction

This chapter describes the environmental consequences of implementing each alternative described in Chapter Two. The environmental consequences or environmental effects will be categorized in three broad areas. The three categories of effects are direct, indirect, and cumulative. These "effect" categories will form the basis of the effects analysis in this chapter.

Direct effects, as defined by the Council on Environmental Quality, are those that are caused by the action and occur at the same time and place. Indirect effects are those that are caused by the action and are later in time or farther removed in distance. Cumulative effects are those that result from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

The cumulative impacts analysis will consider effects of past ranching on the ecosystem, spread of non-native weedy plants, restoration of endemic island fox, and protection of archeological sites.

Connected Actions

It has been determined that fennel control is a connected action to the proposed pig eradication actions. NEPA describes connected actions as those that "cannot or will not proceed unless other actions are taken previously or simultaneously". Because of the density and extent of the fennel on the isthmus of SCI, substantial reduction of the fennel is required to successfully eradicate pigs from this area. Without the reduction of fennel in this area, successful island-wide pig eradication would be compromised. Because fennel control is a necessary action it has been included as part of all action alternatives (Alternatives Two-Four).

As connected actions, the analysis of effects will be evaluated for each separate action (fennel control and pig eradication) as well as the cumulative effects of implementing both actions. In addition, the Park has identified other "reasonably foreseeable" future activities that will be considered in the cumulative effects analysis.

Past, Present, and Reasonably Foreseeable Future Activities

NEPA requires that cumulative effects be considered as part of the environmental effects analaysis. CEQ (40CFR1508.7) defines cumulative effects as: "*the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foresseable future actions regadless of what agency (Federal or non-federal) or person undertakes such other actions*" . Described below are past, present and reasonably foreseeable future activities that have or will be done on Santa Cruz Island.

Past Activities

Human occupation of Santa Cruz Island began approximately 8,000 years ago. European exploration began in the mid 1500's with actual european occupation occurring in the mid 1800's. It is during ths period that much of the decline in the native plant communities occurred due to the sheep and cattle ranching that was introduced during this period. It was also during this period that pigs were introduced to the island. During this era significant vegetation type conversion from native woodland and shrubland to mediterranean grasslands occurred. Removal of the exotic animals is the first step in reversing the downward trend in soil and vegetation resource conditions.

Present Activities

Current management of the island is shared by the National Park Service who owns the east end of the island (24%), and The Nature Conservancy who owns the central and western ends of the island.

Present NPS management (1997-present) of Santa Cruz Island has implemented five major projects. These project include: 1) Temporary administrative housing construction within Scorpion drainage; 2) Scorpion Ranch restoration due to the Scorpion Flood (1997); 3) Scorpion Pier reconstruction; 4) Sewage disposal system in Scorpion Valley; and 5) Prisoners Pier reconstruction (ongoing). Each of these projects had or will have limited resource impacts other than those impacts within the local vicinity of the project. Indirect impacts of rebuilding the Prisoner's Pier may increase visitor use to the NPS owned isthmus. Increased visitor use will be incorporated into the cumulative effects discussion where appropriate.

Present activities associated with The Nature Conservancy include continued fund raising activities associated with the main ranch in the central valley, continued research and monitoring of island resources, and continued conservation work including removing fennel from the central valley.

Future Activities

The General Management Plan provides the basic guidance for the Park on how it will manage protection of Park resources, visitor use, and facility development. However, the GMP for Channel Islands National Park (1980) is out of date for managing the resources of Santa Cruz Island. Since 1980 the Park has acquired 24% of Santa Cruz Island, and has seen visitor use increase dramatically from original estimates in the GMP. Revision of the GMP is expected to begin in FY 2001.

The Park in association with TNC are collaborating their efforts to remove golden eagles from Santa Cruz Island. Park biologists has verified that the decline of the Island fox population on San Miguel, Santa Rosa, and Santa Cruz Island is due mostly to predation by golden eagles. The Park will be collaborating with local conservation organizations to restore bald eagles to the Northern Channel Islands. The process to restore bald eagles is expected to begin in 1-3 years and is being funded by settlement monies from the Montrose DDT lawsuit.

The Nature Conservancy future actions on Santa Cruz Island is focused primarily on collaborating with the Park to eradicate pigs from the island i.e. this DEIS proposal. TNC is working with the California Department of Fish and Game to allow a limited sport hunt of pigs from the island for a short period of time prior to the implementation of this pig eradication proposal. The short-term reduction of pigs that result from the pig hunt would have little effect on reducing long-term pig population or reducing the ongoing pig damage to resources on the island. However, aspects of the activities associated with the pig hunt may have incremental impacts to environmental issues discussed in this analysis. These incremental impacts will be discussed in the cumulative effects sections where appropriate.

Chapter Organization

The Chapter is organized to display environmental effects by Alternative. The four Alternatives appear as major headings (headings are within boxes with white font text). For each Alternative there is an effects discussion (effects analysis) for each environmental issue. Each alternative will include the following actions:

Fennel Control

Pig Eradication

Following the discussion of direct and indirect effects of implementing fennel control and pig eradication, a separate section will discuss the cumulative impacts. The cumulative impacts section will take into consideration the cumulative effects of implementing fennel control, pig eradication, and other "reasonably foreseeable" activities. An outline of a typical Alternative section will be as follows:

The effects discussion will be limited to only the environmental issues that were raised during internal and external scoping. Issues dismissed from analysis can be found in Chapter Two. The scope and indices for measuring environmental impacts for each environmental issue can be found in the section titled, "Significant Environmental Issues", Chapter Two.

Alternative (One-Four)

Environmental Issue

- Effects of Implementing Fennel Control (direct and indirect)
  - Fire Effects
  - Herbicide Effects
- Effects of Implementing Pig Eradication (direct and indirect)
- Cumulative Effects

Alternative One: No Action

Issue 1: Likelihood of Achieving Success

Effects of Not Implementing Fennel Control

It has been determined that fennel control is a necessary component of the Santa Cruz Primary Restoration Plan. The fennel control strategy that is recommended for this project is the minimum set of actions that are needed to reduce fennel cover. Since Alternative One would not enact these minimum control activities, fennel cover would either be maintained or be increased. The existing level of control the Park would invest in the fennel weed problem on Santa Cruz Island would not meet the restoration goals set for this project.

Effects of Not Implementing Pig Eradication

Under this alternative NPS would take no action to eradicate feral pigs from Santa Cruz Island. NPS management of the fennel problem on owned lands would be evaluated in conjunction with weed control needs Park-wide. Fennel control would occur within funding and personnel constraints of the Park.

TNC currently does not have any pig control activities taking place on their lands. TNC has invested considerable resources (Central Valley Fennel Control Project) in determining the most effective way of controlling fennel on their lands. As results of the Central Valley Fennel Control Project are completed, TNC will formulate its fennel control strategy (Aschehoug pers. comm.).

Direct and Indirect - This alternative fails to meet the objective of pig eradication, the most destructive disturbance agent on the island. The goal of protecting island resources could not be met if pigs are not eradicated from the island. These effects (direct, indirect, and cumulative) are covered throughout the rest of this chapter.

Issue 2: Vegetation Impacts

Native Communities

Effects of Not Implementing Fennel Control

Fennel is a highly invasive weed in disturbed areas. In the absence of disturbance the rate of spread of fennel is less than with disturbance. Alternative One would continue to allow disturbance by pigs. Pigs on Santa Cruz Island is the main vector for spread of fennel. Failure to control pigs would result in substantial spread of fennel across the island. Areas infested with fennel, when left untreated, and continually subjected to disturbance, would form dense fennel stands that are void of native plants.

Effects of Not Implementing Pig Eradication

Under this alternative, no eradication efforts would be used on the feral pigs on Santa Cruz Island. Their population numbers would continue to rise and fall with the seasonal and long-term availability of food sources. Feral pigs would continue to impact the native island vegetation including endemic and federally listed plant species.

Impacts to native plants and native plant communities by introduced alien herbivores have been well documented in the literature (Sauer 1988, Hochberg et al 1980, DeBenedetti 1987, Lesica 1995, Painter 1993, Fleischner 1994, and Orodho et al. 1990). Similar impacts have been noted with regards to feral pigs (Brumbaugh 1980, Chipping 1993, and Peart et al. 1994).

Feral pig numbers on Santa Cruz Island are known to oscillate widely between climatic episodes. During the drought years of the early 1990's in California, feral pig numbers on Santa Cruz Island were estimated to be between 500 and 800. Under normal rainfall years and with sheep present only on the eastern portion of the island, feral pig numbers on Santa Cruz Island have been estimated to be as high as 5,000 (Aschehoug, personal communication). When The Nature Conservancy (TNC) removed feral sheep from the main portion of the island, the feral pig population increased and degradation of many of the island ecosystems continued (Peart et al. 1994). With the recent removal of all the sheep from Santa Cruz Island, 5,000 may no longer be an upper limit for the feral pig population.

The feral pig population on Santa Cruz Island will even vary over the course of a year. Numbers normally rise in the spring and summer when food is widely available and then fall dramatically in the fall and winter when food becomes scarce and

starvation becomes common place (Aschehoug, personal communication).

In California, from 1956 through 1991, approximately 750,000 feral pigs were harvested statewide (Peart et al. 1994). These numbers are not surprising given that feral pigs have an extremely high reproduction potential. Conservatively, with plentiful food, feral pigs can be expected to double their numbers at least twice a year (Peart et al 1994). The current number of feral pigs on Santa Cruz Island is approximately 2,500 – 3,000 animals.

The amount of disturbance caused by feral pigs would vary by community depending on access, shelter, water sources, and food availability. Those communities providing adequate water, abundant food sources and shelter would probably incur the most use.

Monitoring of feral pig activities on Santa Cruz Island revealed that they preferred terrain close to cover and north facing slopes, especially during the dry season. This may have to do more with thermo-regulation rather than predator avoidance. Because pigs do not have sweat glands, they are more likely to seek moist, shaded areas during the warm summer and fall months (Sterner 1990). Feral pigs also preferred sites close to water regardless of the season, and they avoided the highest and steepest slopes (Sterner 1990). Similar habitat use has been observed in other parts of the country. In Texas, feral pigs prefer moist habitats when available, with pig distribution limited primarily to bottomland areas (Synatzske in Hellgren 1993).

Although feral pigs on Santa Cruz Island appear to inhabit at least ten of the island communities (Baber 1982), chaparral and oak woodland seem to be the preferred habitats (Sterner 1990). Correspondingly, another study found that feral pigs on Santa Cruz Island preferred chaparral and oak woodland in the dry season and grassland in the wet season (Van Vuren 1984).

Pigs are omnivorous but, in the U.S., tend to have a definite pattern on diet staples throughout the course of a year. In the spring, feral pigs feed on grasses and forbs, followed by fruits and nuts in the summer and fall. Roots, tubers, and invertebrates are consumed throughout the year (Springer, Wood and Roark, Sweeny and Sweeny, Baber an Coblentz in Hellgren 1993). This pattern seems to solely depend on the availability of different food sources.

Direct Effects - Documented direct effects on plant communities by alien herbivores including feral pigs are reduction in native species cover, density, and biomass. Alien herbivores and feral pigs have also caused the elimination of the soil litter layer and loss of seed banks, increased soil disturbance, and soil compaction, and lowered or altered rates and patterns of nutrient cycling (Coonan et al. 1996).

On Santa Cruz Island, acorns and island cherries (*Prunus illicifolia ssp. lyonii*) are preferred diet staples (Schuyler 1988) during the time of year they are available. Feral pig consumption of acorns can reach nearly 100 % (Barrett 1990) in some areas. This level of use could result in complete annual reproductive failure for island oak species. Without adequate reproduction, as the mature older trees die out, entire stands of oaks could be lost. When comparing fenced exclosures versus unfenced study plots on Santa Cruz Island, during normal rainfall years, oak seedling abundance was 85% in the fenced exclosures and only 15% in the open, unfenced plots (Peart et al 1994). There was no significant difference in seedling counts between the fenced and unfenced treatments on the island during drought years (Peart et al 1994). On Santa Cruz Island, only drought stress and feral pigs are known to inhibit oak and woody species regeneration (Peart et al 1994).

In Texas, Synatzske found that feral pigs would concentrate in areas of mast-producing trees (in Hellgren 1993). Although acorns and island cherries are a large part of the feral pig diet on Santa Cruz Island, they are also known to feed

on manzanita berries, roots and tubers, and insects (Burhans in Peart 1994). Barrett (1978) found that brodiaea (*Brodiaea spp*.) bulbs are also a preferred food item for feral pigs. A similar species on Santa Cruz Island, wild hyacinth (*Dichlostemma capitatum*), found in grasslands, chaparral, and coastal sage scrub also appears to be actively consumed by feral pigs (Chaney, personal communication).

When rooting for tubers, corms, or bulbs, feral pigs can till up the soil over a large area to a depth of 2-feet. In a study comparing fenced pig exclosures with unfenced areas on Santa Cruz Island, feral pigs disturbed up to 85 % of the surface area in an unfenced study site (Peart et al 1994). In Hawaii, with the loss of vegetative cover, areas of pig-caused disturbance, lead to increased soil erosion and facilitated the spread of non-native, disturbance adapted plant species (Spatz and Mueller-Dossbois in Hellgren 1993). Feral pigs can also facilitate the spread of invasive, non-native plant species by carrying the seeds on their fur and in their digestive tract. These seeds are then deposited in the freshly churned soil. Once established in an area, invasive non-native species can out-compete native plant species for available resources.

In searching for food and shelter, feral pigs create winding trails through all plant communities. These paths compact the soil and contribute to increased water run-off and erosion. These paths can also serve as routes for the spread of invasive, non-native plants species. Where they intersect maintained Park trails, these pig trails can also lead visitors astray (Willy 1987).

Indirect Effects - Documented indirect effects of alien herbivores and feral pigs to plant communities include the increase of cover, frequency, and bio-mass of non-native plants species, increased water run-off and soil erosion, and degradation of soil structure. Feral pigs have also contributed to changes in the soil micro-flora and micro-fauna, and the potential loss of fire-induced successional communities due to inadequate fuels and lack of seed banks (Coonan et al. 1996). In Tennessee, indirect effects associated with feral pigs included setting back or speeding up plant succession, consumption of natural seed crops to the point of impeding reproduction, limiting species composition and quantity of vegetation, encouraging erosion and physical damage to trees (Hellgren 1993).

Disturbances caused by feral pig rooting and movement through island vegetation may facilitate the spread of non-native, invasive plant species. Once established these species have demonstrated the ability to expand at the expense of native plant species (Sauer 1988). Additionally, many of naturalized exotic plant species found on Santa Cruz Island have co-evolved with the grazing pressures exerted by large herbivores. They have adaptive mechanisms, which allow them to avoid being grazed or to better survive the impacts of grazing. These exotic plant species have expanded in the presence of feral sheep and cattle on Santa Cruz Island at the expense of the islands native flora. The presence of feral pigs would only likely benefit these species.

Micro-biotic flora or crusts are a critical component of many of the arid and semi-arid rangelands throughout the North American west (Johansen 1986). These crusts are found throughout the world and are known to occur on Santa Cruz Island. Cyano-bacteria make up the majority of the micro-biotic crusts but lichens, mosses, green algae, micro-fungi, and bacteria are present as well. These soil crusts significantly modify the surfaces on which they occur and can represent 70-80 percent of the living ground cover (Belnap 1994). Soil crusts are known to be important in nitrogen fixation, enhancing vascular seedling establishment, and reducing soil erosion (Snyder and Wullstein 1973, St. Clair et al. 1984, Bailey et al. 1973).

Several studies have shown that soil crusts are severely impacted by the trampling associated with grazing (Rogers and Lange 1971, Kleiner and Harper 1977, Brotherson et al. 1983, Johansen 1986, Anderson et al. 1982, Cole 1990).

Researchers have noted that soil lichen cover is negatively correlated with livestock grazing and that soil mobility and erosion increased with reduced lichen cover (Rogers and Lang 1971). It is likely that feral pig rooting would be equally as damaging. Recovery of soil crusts following the cessation of grazing and trampling has also been noted (Johansen et al. 1986, Cole 1990). This recovery seems to follow a certain pattern in that the algae component of the soil crust is the most resistant to disturbance (Anderson et al. 1982) and is the quickest to recover (Johansen et al. 1984). The lichen and mosses component on the other hand recovers much more slowly.

Cumulative Effects

Forbs - Under the no action alternative, fennel will continue to invade disturbed communities of Santa Cruz Island crowding out native forbs. Invasive forb species such as yellow star thistle (*Centaurea solstitialis*), tocalote (*Centaurea melitensis*), hoary cress (*Cardaria draba*) and a variety of other Brassicaceae and other species will also take advantage of pig rooting disturbance and spread throughout native plant communities.

Grasses - The no action protocol will allow for continued disturbance on Santa Cruz Island by feral pigs. These disturbances will continue to be vectors for invasion by Mediterranean annual grasses. There is no evidence either way that feral pigs have a positive or negative impact on native perennial grasses. If rooted extensively, native perennial bunch grasses would likely die, which would decrease the already dapauperate native bunch grass communities.

Shrubs – The no action protocol will allow for persistent disturbance by feral pigs on Santa Cruz Island. These disturbances will continue to be vectors for invasion of fennel, Mediterranean annual grasses, and invasive forb species. With the constant disturbance by pig rooting, native shrub communities will continue to become invaded with these noxious weed species, and some native shrub communities will be out-competed (i.e. coastal sage scrub) and removed from the system.

Historic - Cumulative effects are those factors or activities which in the past, present, or future have affected native plant communities. Past activities may have included the manipulation and use of plant communities by native americans prior to European arrival. Early native americans were hunter-gatherers which relied heavily on fishing and harvesting marine resources (Junak et al 1995). By the early mission period, there were 11 Chumash villages on Santa Cruz Island with a total population of more than 1,100 (Glassow 1980). Native americans probably affected the plants and plant communities of Santa Cruz Island by selectively harvesting plants for food or other uses. They may also have altered habitats near their villages, and they are known to have transported plant materials from the mainland and between islands (Juank et al 1995). The Chumash may also have deliberately set fires for vegetation management purposes (Carroll et al. 1993).

Historic impacts also occurred and were greatly accelerated with European settlement of Santa Cruz Island in the 1800's. Activities associated with settlement included the clearing and farming of certain areas on the island; the establishment of grapes, olive trees, eucalyptus; and the introduction of sheep, pigs, cattle, and horses. By the late 1800's several ranches were established on Santa Cruz Island. The introduction of non-native plant species continued and included fruit trees, Acacia trees, Italian stone pines, cypress, alfalfa, walnut, and cultivated vegetables. Of these activities, by far the one that would most impact the native vegetation was the introduction of sheep. By 1875, there were an estimated 60,000 sheep on the island. In 1939, following several one-shot efforts, a systematic roundup of the sheep was begun. Around 1954, it was reported that approximately 35,000 sheep were caught and sold but that many more remained. Between 1955 and 1962, almost 30,000 more sheep were caught and sent to market and during the 1960's

and 1970's an estimated 180,000 sheep were shot and killed (Junak et al. 1995). By 1980, after decades of overgrazing by sheep, most of the islands plant communities had been adversely affected. These effects included changes in population structure and species diversity. Species distribution had also been affected. Some native species such as giant coreopsis, Humboldt lily, and northern island hazardia had their ranges reduced; while other native species like dove weed (Eremocarpus setigerus) and opuntia (Opuntia spp.) increased their ranges (Junak et al 1995). These impacts are still very much evident but with removal of the last feral sheep in 1999, native vegetation has shown signs of some recovery.

Present – Present park activities which could impact native plant communities include: public recreational activities, road maintenance and grading, research projects, monitoring efforts, global weather patterns, and human induced climatic shift. The first four activities occur on a seasonal basis and are usually contained within limited physical boundaries. Recreational activities include camping and hiking on land and kayaking on the surrounding waters. Hiking and camping are limited to identified camping areas and hiking trails, although some hiking off-trail likely occurs. Physical disturbances are associated with these activities however and native vegetation is usually trampled and crushed around campgrounds and hiking trails. The use of these areas also compacts the soil, which increases water run-off and soil erosion. The disturbance nature of trails and campgrounds facilitates the spread and establishment of invasive non-native plant species. Similar effects are seen with road grading and maintenance. Russian thistle (*Salsoa tragus*) has been spread along the south side of Santa Rosa Island due to grading activities (Chaney, personal observation). Yellow star thistle (*Centaurea solstitialis*) has likely been introduced and spread on Santa Rosa Island recently due to the activities of private sport hunters (Chaney, personal communication). There are little or no impacts, to the islands native flora, associated with sea kayaking.

Research projects and monitoring activities are varied in nature and can occur throughout the year but usually take place in the spring and summer. Research projects on Santa Cruz Island are initiated or approved by NPS, TNC, and the UC reserve. Most of the research projects taking place on Santa Cruz Island have little or no physical disturbances associated with them and impacts to islands native plant communities should be minimal.

Impacts are associated with the Channel Islands Terrestrial Vegetation Monitoring program. These impacts include the trampling and crushing of native vegetation, the accidental uprooting of herbaceous plants, the accidental breakage of native tree and shrub branches, and the collecting of plant specimens for the Channel Islands National Park herbarium. These impacts are limited in scope and are usually confined to the areas where permanent transects have been set. On Santa Cruz Island, within the National Park Service boundary, there are 22 vegetation transects in place. Ten additional transects will be set up later this year. The protocol is to read these transects annually in the short-term to capture any initial changes in the vegetation following the removal of feral sheep and possibly feral pigs from the island. There are approximately 75 similar transects set up by TNC on the main portion of the island. These transects are not currently being read but that may change in the future.

Future – Future cumulative impacts to native plant communities could be caused by recurring natural shifts in weather patterns. This has been evidenced most recently with the El Niño/ La Niña weather pattern. During El Niño events the easterly surfaces winds in the Pacific weaken causing the winds to shift to a westerly flow followed by stormy weather west of the International Dateline. Within several weeks, the Pacific Ocean reacts to the changes in wind speed and direction. In the past, sea levels have risen by

up to one foot in the eastern Pacific to Ecuador, with a corresponding drop in the western Pacific. Sea temperatures have also risen along the whole expanse of the Pacific' coastline stretching from Chile to British Columbia. These changes in wind direction and ocean temperatures are accompanied by changes in the global climate. In effect during an El Niño event, the rain area that is usually centered over Indonesia and the far western Pacific moves eastward in the Central Pacific, this causes unseasonable weather over many regions of the globe including California. Typically, California experiences more intense storms and increased precipitation during El Niño years. Again, for healthy plant communities such events may not pose a great risk. For damaged plant communities or rare plant species such changes may present more of a threat.

Increased rainfall can be beneficial to native plant communities but increased water run-off and erosion can cause negative impacts as well. It is likely that some species benefit more from the increased precipitation than others.

La Niña is another natural climatic shift, which can cause impacts to native, island vegetation. La Niña events are almost the direct opposite of El Niño events. Under a La Niña episode, the ocean temperature in the Pacific is colder than normal, which tends to bring climatic shifts that are opposite of those produced in El Niño years. For California, this usually means that winters are warmer and drier than in normal years bringing drought like conditions with attendant impacts to native, island flora. Water stress in individual plants can cause decreased vegetative and reproductive growth and reduced resistance to insects and disease.

Global warming, caused by the greenhouse effect, is a man-caused condition which is expected to modify the world's environment to an as of yet unknown degree. Any climatic changes associated with global warming could have significant impacts to native, island flora. Changes from global warming are ongoing and are affecting us today. Currently there is some controversy about global warming but what is known is the earth's mean surface temperatures have increased .6-1.2 degrees F since the late 19th century. Globally sea levels have risen 4-10 inches and worldwide precipitation over land has increased by about one percent. The frequency of extreme rainfall events has also increased throughout much of the United States. Predications about the future are uncertain but scientists expect that the average global surface temperature could rise 1.6-6.3 degrees F by 2100 with significant regional variation. As the climate warms, evaporation will increase which will increase global precipitation. Soil moisture is likely to decline in many regions with the increase in temperatures while intense rainstorms are likely to become more frequent. The sea level may rise up to two feet along the U.S. coast (U.S EPA 2000). World wide climatic changes such as these are bound to impact vegetation on a local and regional level. The flora of the Channel Islands and on Santa Cruz Island will undoubtedly be impacted to some degree. Current native species composition and frequency which is already undergoing change and recovery from past land management activities and the introduction of non-native plant species will react to these climatic changes. Some species may benefit from these forecasted changes while others will be negatively impacted, either slightly or severely. Some species which have been severely impacted by the island's past grazing history may perish with additional stress. It is likely that those plants, which are currently rare, will be the most at risk.

Threatened and Endangered Plant Species

Effects of Not Implementing Fennel Control

Invasive, non-native plant species like fennel outcompete native plant species for available nutrients and water. When fennel invades native plant habitat replacing the native diversity

associated to the site, the site no longer provides suitable habitat for the threatened or endangered species. Having limited habitat for T& E species can lead to the local extirpation of listed plant occurrences. Infestations of non-native invasive plant species like fennel can alter the micro-habitats of an area. This could render these sites unsuitable for those species occupying the site or it could prevent the expansion of listed plants into what otherwise would be favorable sites. Limiting the number of suitable habitats for rare plant species further exposes the present occurrences to extinction through random stochastic events.

Effects of Not Implementing Pig Eradication

In the *Thirteen Plant Taxa from the Northern Channel Islands Draft Recovery Plan* (USFWS 1999), feral pigs were identified as a potential threat to each of the nine listed plant species found on Santa Cruz Island (see table x).

Under this alternative the threats to each of the listed species would remain. Fluctuations in the severity of impacts would occur seasonally and yearly as feral pig numbers changed. However, the potential for recovery of rare plant species would still be negligible even during those years when feral pig numbers are low. This is because the number of feral pigs on Santa Cruz Island is tied to food availability. Pig numbers are lower during drought years when little food is available but these periods of low rainfall would also likely inhibit overall plant growth and reproductive success in those plants that are rare. Therefore, the chance for extirpation of occurrences and species extinction would continue to be higher in all years with pigs, than in the absence of feral pigs.

Direct Effects - Direct impacts to listed plant species would include herbivory of T&E plant species by feral pigs and the trampling, crushing, and uprooting of listed plant species should feral pigs walk, root, or bed down within listed plant occurrences. Depending on the number of individual pigs within an area, one to many T&E plants may be grazed, trampled, or uprooted. Those occurrences that are found in areas of high pig use would likely incur the most damage. Because the rarity of these listed plant species is defined by their limited numbers, even relatively small impacts can have a large detrimental effect. Individual plants lost through predation, trampling, or uprooting cannot contribute off-spring to the succeeding generation. This results in a loss to the next generation in both absolute numbers and potential genetic diversity. A decrease in genetic diversity can lead to an overall decrease in evolutionary fitness for a species. Decreased population numbers leads to increased potential for extinction from continued predation, or from large random disturbance events such as a fire, earthquake, or landslides.

Table 6. Santa Cruz Island federally listed as threatened or endangered plant species

Scientific Name	Common Name
Arabis hoffmanii	Hoffman's rock cress
Berberis pinnata ssp. Insularis	Island barberry
Dudleya nesiotica	Santa Cruz Island dudleya
Galium buxifolium	Island bedstraw
Helianthemum greenei	Island rush-rose
Malacothamnus fasciculatus ssp. nesioticus	Santa Cruz Island bushmallow
Malocothrix indecora	Island malacothrix
Malacothrix squalida	Santa Cruz Island malacothrix
Thysanocarpus conchuliferus	Santa Cruz Island fringepod

Indirect Effects - Indirect effects include alterations in listed plant micro-habitats, soil erosion, and facilitation of the spreading of invasive, non-native plants into the habitats of listed plant species. Disturbances caused by feral pigs in and around listed plant occurrences can lead to increase erosion within those occurrences. This increased erosion can expose the roots of listed plant species inhibiting water and nutrient uptake or in severe cases completely up-root individual plants. Disturbances caused by feral pig foraging and rooting can also facilitate the spread of invasive, non-native plant species within listed plant occurrences. Invasive, non-native plant species can out-compete native plant species including listed plants for available nutrients and water. This can lead to the local extirpation of listed plant occurrences. Infestations of non-native invasive plant species can also alter the micro-habitats of an area. This could render occupied habitat unsuitable for those species occupying the site or it could prevent the expansion of listed plants into what otherwise would be favorable sites. Limiting the number of suitable habitats for rare plant species further exposes the present occurrences to extinction through random stochastic events.

Feral pigs, like all animals, excrete excess nutrients and waste in the form of urine and feces. Chemicals, primarily nitrogen, in urine can chemically burn individual plants and alter the micro-habitats around the point of urination (Williams and Haynes 1994). Pig feces can cover individual plants blocking their access to sunlight, reducing the plant's vigor and health (Williams and Haynes 1995). Adjacent plants may benefit from the extra nutrients available in urine and feces similar to the effects seen with the application of normal fertilizer. Increased nutrient availability may still be evident three years after deposition of dung (Williams and Haynes 1995).

Cumulative Effects

If the no action alternative is taken, the nine listed plant species (see table x) would continue to be threatened due to pig associated activities. Specifically, *Galium buxifolium* will continue to be grazed and rooted by feral pigs. Any grazing and rooting that currently occurs on the population will continue to degrade the endangered species, and may eventually lead, if management actions are not taken, to the extinction of the isthmus populations of *Galium buxifolium.*

Cumulative effects are those factors which in the past, present, or future have affected TES plant species. All species - but especially those with small population sizes - face the threat of extinction. Threats to a species survival include competition from other species, disease, predation, habitat loss, long-term environmental trends, and catastrophic events. Species with small populations also face threats to their gene pool from inbreeding, loss of heterozygosity, and, for those species arising from colonization and subsequent adaptive radiation, possible Founder effects. There is no clear indication however whether a decrease in genetic diversity leads to a decrease in species fitness (Shafer 1990).

Cumulative effects, which may impact listed plant occurrences, are similar to those listed for plant communities but the consequences may be more severe. Because listed plant species are rare and limited, often both in absolute numbers and number of occurrences, impacts to a portion of a population can have severe consequences. Common plant species are often extirpated in localized areas, either from natural disturbance events or human caused disturbances. These areas are usually eventually re-colonized however, from seed stored in the soil or propagules from adjacent areas. Rare plants species on the Santa Cruz Island don't have those options because either their seed bank has been severely disrupted from years of over-grazing or distances between known occurrences are usually too great to allow for re-colonization.

Fennel

Effects of Not Implementing Fennel Control or Pig Eradication

Fennel control is a connected action to the eradication of pigs on Santa Cruz Island. Failure to treat the fennel to a condition where hunting can be successful in these stands would compromise the efficacy of pig eradication. Fennel would continue to spread on the island and this spread would greatly be enhanced by pig disturbance.

Cumulative Effects

The uncontrolled pig population on Santa Cruz Island has been linked to many island-wide resource impacts. Failure to eradicate pigs from the island would mean that those identified impacts would continue.

Specifically, the decline of the Island Fox population has been attributed to Golden eagle predation on the fox. Golden eagles, in part, are present year round on the island because piglets are an abundant food source for them. Impacts to the Island Fox would continue as pigs remain on the island.

In addition, pigs in their search for food cause much soil and vegetation disturbance. The soil disturbance affects watershed health, sensitive cultural resources, and T&E plant species. Without pig eradication these resource impacts would continue to occur.

Under Alternative One no pig eradication or fennel control action would be done. Continuation of the existing management efforts to control fennel and pigs would continue. However, it has been demonstrated by TNC that control of pigs still causes undesirable resource impacts.

Fennel will continue to spread throughout the isthmus out-competing native plant species and invading native plant communities where feral pigs cause disturbance. Feral pigs will continue to thrive in the fennel spreading the invasive species, breeding, and causing further degradation.

Other Weeds

Effects of Not Implementing Fennel Control

Fennel covers over 10% of Santa Cruz Island (Klinger unpublished data), and is currently spreading along roadsides into many coastal sage, grassland and bare/disturbed sites. As noted earlier, fennel control is necessary for pig eradication to be successful. With continued pig presence, disturbance would continue creating suitable habitat for weed colonization.

Effects of Not Implementing Pig Eradication

Implementation of Alternative One would result in large and rapid increases in distributions and abundance of invasive alien plants on the island, and will produce heavy and long-term negative consequences to the success of NPS and TNC weed management programs. The current trends of increasing distributions and abundance of many alien species are likely to continue and accelerate. The largest numbers of these species are concentrated in the areas of highest pig population density. Some impacts and trends will be permanent and irreversible.

Dispersal of weed seeds by pigs from infested to un-infested areas will continue. Prevalence of favorable weed-seed germination conditions created by pig rooting and trailing will also increase.

Issue 3: Island Fauna Impacts

Native Island Fauna

Effects of Not Implementing Fennel Control

Fennel control consists of both burning and herbicide activities. Both of these activities can have impacts to native fauna that utilize the fennel stands. Fires generally change the structure of the community making them more open. By keeping intact the thick fennel stands habitat would benefit species that prefer a more relatively closed community, specifically the Southern Alligator lizard.

Effects of Not Implementing Pig Eradication

The feral pig population would continue to fluctuate due to annual differences in weather. In years with favorable precipitation, greater plant productivity would allow pig populations to expand. Conversely, during periods of drought pig populations would decrease.

Pigs would have significant and adverse effects on island wildlife and fauna under this alternative. Pigs would continue to cause direct mortality of invertebrates during certain times of year, since invertebrates are a part of their diet. However, it is doubtful that pig foraging would have significant effects on invertebrates at the population level.

Under this alternative pigs would continue to adversely impact wildlife on Santa Cruz Island, primarily by destruction of suitable habitat. Pig rooting in specific locales would destroy habitat for rodents, lizards, snakes, salamanders, foxes and skunks. Pigs would also continue to directly consume small vertebrates when encountered. Pig use of riparian areas would adversely impact frogs, salamanders, and aquatic invertebrates. Because feral pigs prefer mast crops, pig rooting for acorns in years of significant mast would impact those species, such as the Santa Cruz Island jay, which depend upon mast crops.

Pig carcasses would continue to be a food source for ravens, perhaps maintaining them at levels which allowed raven predation on other species (such as snowy plovers) to be significant.

Under this alternative pigs would continue to form the primary prey base for non-native golden eagles. Although 13 golden eagles were removed from Santa Cruz Island in 1999-2000 as part of island fox recovery actions, the continued presence of feral pigs could still attract and support a breeding population of golden eagles on Santa Cruz Island. In turn, a population of eagles supported by feral pigs could drive island fox populations on the northern Channel Islands to extinction. Because of their large territories, eagles breeding, wintering or roosting on Santa Cruz Island could easily prey on island foxes on Santa Rosa and San Miguel Islands. There are approximately five golden eagles remaining on Santa Cruz Island. Predator-prey modeling indicates that as few as two eagles could have been responsible for the observed decline of island foxes on San Miguel Island.

Cumulative Effects

Alternative One, the no action alternative, should have no additional effect on vertebrate species. Those birds foraging on invertebrates within the fennel will continue to forage. Southern Alligator lizards will continue to be the dominant herpetofauna in the fennel, and the small mammals that seek cover in the dense fennel will continue to hide there.

With the continued spread of fennel, those vertebrates that use other plant communities encroached by fennel will be negatively effected by the spread of fennel and the continued rooting of feral pigs.

Alternative One, the no action alternative, should have no effect on invertebrate species located within the fennel monocultures. The spread of fennel and the continued rooting of feral pigs will negatively effect invertebrates that use plant communities less vertically diverse than fennel.

Non-native Fauna (Pigs)

Effects of Not Implementing Pig Eradication

Under this alternative, the feral pig population would continue to fluctuate due to annual differences in weather. In years with favorable precipitation, greater plant productivity would allow pig populations to expand. Conversely, during periods of drought pig populations would decrease.

During periods of drought, many pigs would die of starvation.

Some piglets would die annually due to golden eagle predation.

Issue 4: Impacts to Physical Resources including Soils, Water and Air Quality

Effects of Not Implementing Fennel Control

Indirectly, because the fennel stands are rooted through by feral pigs, soil disturbance and erosion is common in these areas. Soil erosion results in loss of soil from the site but can result in loss of nutrient availability and the creation of gullies.

The prescribed burn to treat fennel would not occur; therefore no fire emissions would occur that would adversely affect air quality.

Effects of Not Implementing Pig Eradication

Because sheep have been removed from Santa Cruz Island, direct impacts from overgrazing from sheep have ceased. However, soil disturbance from pig activities continues. This alternative would not implement any significant reductions in the pig population. Pigs would continue to root for food causing continued soil disturbance. This soil disturbance eventually results in soil erosion.

Slopes whose vegetation and soils have been upturned and tilled as a result of pig rooting are susceptible to having rapid runoff during storm events. This rapid runoff would continue to deepen existing gullies, and possibly create new gullies. Rapid runoff causes high sedimentation to occur in low gradient valleybottom reaches.

High sedimentation rates with low watershed slope stability would be a primary concern for decline in water quality for the island.

Cumulative Effects

Under Alternative One, fennel will continue to spread on the isthmus, releasing potentially allelopathic secondary compounds into the soil. These compounds may suppress possible regeneration of native species within the vicinity of *Foeniculum vulgare* (Colvin 1996). Pigs will continue rooting along the isthmus causing more soil erosion and more potential patches for fennel and other invasive species invasions.

Issue 5: Socioeconomic Factors including Cultural Resources and Human Uses

Cultural Resources

Effects of Not Implementing Fennel Control or Pig Eradication

Under this alternative, damage to archeological sites by feral pigs would continue essentially unabated. Continued pig rooting of archeological sites on the island will result in their loss of integrity, and ultimately loss of the values which make the Santa Cruz Island archeological district eligible for the National Register of Historic Places.

Pig rooting is currently estimated to have damaged nearly all of the archeological sites on the island, to a minor or major extent. Pig rooting to a depth of three feet has been noted in a number of sites, particularly in areas covered by fennel or wild cucumber (Don Morris and Dr. Jeanne Arnold, personal communications). The information potential of some shallow sites and surface scatters has been completely destroyed by pig rooting. Rooting in the upper layers of deeper, more complex, stratified sites profoundly disturbs time and spatial relationships and destroys the context of the information contained in these sites. In addition, pig rooting has disturbed ancient burials found in many locations on the island.

NPS would continue to try to prevent complete loss of the archeological record by fencing a small number of sites each year, as funds allow. This, however, is a costly alternative that preserves only a small number of sites and requires constant monitoring to ensure that the fences are adequately keeping out the pigs. This alternative also does not preserve the archeological values that were recognized in the park's enabling legislation or the values for which the island was listed on the National Register.

The Santa Cruz Island archeological district is significant for the large number and diversity of pristine sites found on the island. Sites range from isolated artifacts to huge, stratified sites encompassing habitation areas and specialized activity areas spanning a period of 8,000-9,000 years. Continued pig depredations throughout the island, with small-scale NPS efforts to fence and protect sites, will result in a truncated archeological database. The number and diversity of sites will be greatly reduced, destroying the values of the district, and resulting in de-listing of the National Register district, possibly leaving a small number of individually eligible sites. The value of remaining archeological sites will be greatly reduced, and future researchers will be unable to take advantage of new research techniques that may be developed in the future.

Human Uses

Effects of Not Implementing Fennel Control

Under Alternative One existing socioeconomic conditions would continue on Santa Cruz Island, with visitation increasing on the newly acquired isthmus. Visitation will continue to be heavy in the Scorpion area, but less so at Prisoner's, due to lack of services and visitation options. The visitor experience will be somewhat impacted by the presence of feral pigs and by the effects of feral pigs, which include evidence of pig rooting, the occasional sighting of feral pigs, and continued impacts to native wildlife such as island foxes, which will continue to be at risk until pigs are removed from the island.

No visual impairment due to smoke generated from the fennel prescribed burn would be realized. Emissions from a prescribed fire, which could affect air quality, would not be generated.

Alternative Two: Simultaneous Island-wide Eradication of Pigs

Issue 1: Likelihood of Achieving Success

Effects of Implementing Fennel Control

The recommended action for fennel control is consistent for alternatives Two-Four. Based on TNC sponsored research, the recommendations provided in this proposal were shown to control fennel better than other tested techniques. Based on this, the recommended fennel control actions meet the stated goals for fennel management.

Effects of Implementing Pig Eradication

In November 1998 the NPS and TNC assembled a group of pig control experts, including biologists and land managers, on Santa Cruz Island to discuss the issue of feral pig impacts and recommended management actions. The group unanimously determined that eradication of feral pigs should be of the highest priority for the management agencies due to the pervasive impacts of pigs on natural and cultural resources. Of all the pig eradication alternatives available, the team determined that island-wide eradication was the preferred option if resources (personnel and budget) were not a limiting factor.

Direct and Indirect - As demonstrated by the group consensus favoring this eradication strategy, this alternative has high probability of success for pig eradication. However, potential for failure exists should resource constraints become evident at any time during project implementation. This alternative is totally reliant on amassing a high intensity eradication effort for a concise short duration of time. Failure to maintain either component (high intensity or short duration) would result in a lower probability of success.

Issue 2: Vegetation Impacts

Native Communities

The effects analysis in this section assumes that feral pigs would be eliminated following the fennel control treatment. Long-term pig disturbance following fire would compound the negative effects of the fire and contribute to the decline of native species. As a connected action the Park would not implement the large scale fennel treatment unless pig eradication is attempted as well.

Effects of Implementing Fennel Control

Fire and herbicide effects would be the same for Alternatives Two, Three, and Four.

Fire Effects

Forbs - Most native and invasive forb species have set seed well before October or November, the approximate time of fire prescription. The fire should not directly affect forb seeds in the seedbank. The prescribed burn will remove most, if not all, above ground forb biomass transforming the plants' masses and nutrient contents into ash.

The ash produced by the prescribed burn will increase the nutrient content of the soil, which will increase nutrient availability to forb seedlings. With sufficient water availability, the increased soil nutrient content will allow for a flush of spring forb growth the year following the prescribed burn. Decreased above ground litter will also allow for greater photosynthetic photon flux density for those forbs that were light limited.

Grasses - The prescribed burn will consume most, if not all of the dead aboveground biomass of the annual grasses. Depending on the intensity of the fire, some of the perennial grasses will be consumed and killed in the fire. The majority of perennial grasses should survive the prescribed burn and re-sprout the following spring (Erskine unpublished data). The prescribed burn should not affect the seedbank of either the perennial or annual grasses (Erskine unpublished data).

As with the forb species, the ash produced by the prescribed burn will increase the nutrient content of the soil, which will increase nutrient availability to grass seedlings and re-sprouting perennial grass tussocks. With sufficient water availability, the increased soil nutrient content will lead to a flush of spring grass growth the year following the prescribed burn. Decreased above ground litter will increase photosynthetic photon flux density to seedlings. Managers should be wary of a flush of Mediterranean annual grasses. Such species are good competitors against native

species (native forb, grass and shrub seedlings), and active management may need to occur to prevent a type conversion of these communities into Mediterranean grasslands. Generally, a single burn is not enough for such a process to occur.

Shrubs - Single fire events do not negatively affect chaparral and other California/Santa Cruz Island shrub communities. Most native shrubs (if not all) that were burned during the fall 1997 fire conducted in Santa Cruz Island's Central Valley fully recovered, and in certain areas, appear to be doing better than unburned areas of chaparral. (For example in the Central Valley- *Ceanothus sp.* (California lilac) and *Lupinus sp.* (lupine) flowered prodigiously in the areas of fire escape in spring 2000). Fire will burn the outer branches of the shrubs, but most native California shrubs are adapted to fires and will resprout from the crowns and buds on burnt branches. Even those shrubs said to be sensitive to fire (*Artemesia californica*-coastal sagebrush) have the ability to resprout from single fire events. The continuous use of fire kills such "sensitive" established shrubs (Mooney and Drake 1986).

Fire has been shown to promote the seed germination of many chaparral shrubs including *Arctostaphlos sp.* (manzanita) and *Adenostoma fascilulatum* (chamise) (Everett 1957, Emery 1964, Keeley 1987, Keeley and Keeley 1987) both present in the native plant communities (Minnich 1980). Seed germination of these shrubs will encourage the recruitment of such shrubs into the fennel-infested community.

Herbicide Effects

Forbs - As with fennel, forbs will readily absorb Garlon 3A, a broad-leaf herbicide. Symptoms of Garlon toxicity can include epinasty of the leaves, petioles, and stems, growth inhibition, wilting, chlorosis at the meristems, and necrosis (Ahrens 1994). Forb species will die within 3-5 weeks.

Most forb species within the grassland/fennel infested areas are ephemeral and have set seed by late April (protocol recommends an early May herbicide spray). Garlon only affects' growing plants and will not affect seeds in the seedbank. Sensitive communities such as riparian communities, cliff embankments, and oak woodlands, which contain forb species as well as woody dicots, should be avoided with the herbicide spray. If those communities receive the herbicide, it is likely that there will be accidental deaths.

Included in grassland and disturbed community forb species are a variety of invasive species such as *Centaurea solstitialis, Centaurea melitensis,* and *Cardaria draba*. These species are late bloomers (especially *Centaurea* sp.) and may be sprayed with Garlon before fruiting. This allows Garlon not only to eliminate some of the *Foeniculum vulgare*, but also to prevent invasion by a different noxious weed. Prevention of these weeds and fennel will allow for further native community development. The last impediment on native forb and woody community development could be the invasion of these disturbed areas with Mediterranean annual grasses. If the area begins to become invaded by Mediterranean grasses, restoration measures such as out-planting of native species should ensue.

Grasses - There are no direct effects of Garlon on grasses. Garlon is a herbicide that specifically targets the metabolism of dicot species. Garlon 3A will indirectly effect grasses by killing/decreasing fennel and other dicot species allowing for greater of both native and nonnative grass species establishment the following spring. The annual and perennial dicot species will release a larger quantity of nutrients into the soil because they will die before reallocating nutrients from leaves and stems into seeds. The macronutrients and micronutrients from decaying plant tissue will go directly into the soil for microbes and other plant species to sequester. Most native and non-native annual forb species associated with fennel have set seed by late April; therefore those species will not indirectly affect the grass species. Such forb species will have the

same advantages of nutrient fluxes and light fluxes as the grasses.

Shrubs - Garlon 3A produces epinastic bending, chlorosis, growth inhibition, irregular appearances and wilting in many dicot plant species (Ahrens 1994). Although Garlon will negatively effect native shrub species that come in contact with the herbicide, these plant species will not likely be killed. Necrosis of the leaves and branches is common, and the appearance of death may even occur, but many dicot shrubs resprout from the crown the year after, and sometimes the summer after coming in contact with the herbicide (Erskine personal observation). Native California shrubs are adapted to harsh xeric conditions and contain thick waxy cuticles on often evergreen leaves. These leaves do not readily absorb the herbicide, and although the plants may be injured by the herbicide, they do not often die.

Indirectly, the herbicide will negatively affect the fitness of shrubs that are sprayed. Most shrubs sprayed with the herbicide will use their nutrient supplies to recover from the spray, and will not reproduce that year (Erskine personal observation). Shrubs observed in the Central Valley Fennel Removal Project recovered from two successive years of spray with Garlon 3A.

Assessment of effects assumes that feral pigs are eliminated following treatment. Long-term pig disturbance following fire would compound the negative effects of fire and contribute to the decline of natives. It is recommended that fennel treatment not occur unless pigs are removed from the fennel treatment areas.

Effects of Implementing Pig Eradications

Alternative Two would involve the use of five teams of hunters and dogs simultaneously in an island-wide intensive hunting effort. This eradication effort would be expected to last 2 years. Extensive stands of wild fennel (*Foeniculum vulgare*) in the isthmus area would be treated with a combination of prescribed burning and the application of the herbicide Garlon.

Negative effects to native vegetation and individual plants by the five teams of hunters and dogs would be short-term and likely insubstantial. Short-term impacts to native vegetation would occur as feral pigs are chased and cornered. These impacts would include trampling of the vegetation, damage to individual plants as leaves, branches, and shoots are torn by running animals and hunters. Additionally, even with the current road system, the teams would create trails as they moved between different areas on the island. These trails would compact the soil and could facilitate the movement of non-native, invasive plants into previously non-infested areas.

The seeds of invasive non-native plant species could also be carried on the boots and clothing of the hunters as well as in the fur of the hunting dogs. Vehicles used by the hunting teams can also transport non-native plant seeds in their tires and the under-carriage. Areas where invasive plant species are transported and become established would require active treatment to prevent trading one problem for another.

The formation of new trails could also lead to a short-term increase in soil erosion. The increase in soil erosion and the impacts to the soil micro-flora would likely decline once the pigs are eradicated from Santa Cruz Island and use of the hunting trails is discontinued. However some of the soils on Santa Cruz Island are highly erodible and the possibility exists that the new trails could cause substantial erosion and gullying without remedial action.

Trampling of the soil by vehicles and the hunters can cause alterations in the soil micro-flora and cryptobiotic soil crusts may be damaged. As discussed previously, cryptobiotic soils are important components of soils in arid and semi-arid environments. Trampling, especially during the dry season easily damages these soil crusts. These soil crusts have the ability to re-colonize disturbed areas from nearby non-disturbed land,

however re-colonization and re-establishment of soil crusts in an area can be somewhat slow depending on various environmental factors.

There is also an increased risk in starting an accidental fire under this alternative. Hunters could start a fire primarily in one of two ways. By a hunter who might smoke and absentmindedly toss a cigarette away in the course of the hunt or by a spark generated from the ricochet of a bullet. A mandate of no smoking may decrease or eliminate the first cause but there is no remedy for the second. Because fire suppression resources are limited on Santa Cruz Island, the potential exists for any fire to rapidly spread.

A large accidental fire could have a devastating impact to island plant communities that are just recovering from almost a century of severe grazing. In a healthy Mediterranean plant community, the occurrence of a fire is not necessarily adverse. In many cases, fire is a beneficial and integral mechanism by which the community renews itself. Many plant species in Mediterranean ecosystems have adaptive mechanisms in response to fire. Some plant species such as toyon, oaks, lemonade berry are termed obligate sprouters. This is because although their seeds may not survive the fire, they resprout vigorously after fires. Other species however, produce large amounts of seed (obligate seeders) which accumulate in the soil seed bank. Once a fire has passed through, the heat or smoke from the fire will cause these seeds to germinate. So, even though the parent plant may not survive, there is a high probability that it will be replaced by its progeny in the plant community. The problem for these plants occurs if continual disturbance from severe grazing has led to accelerated erosion and the subsequent loss of the seed bank. If a fire should occur before this seed bank is replenished, there will be no replacement for the parent plant. This is the state that some of the plant communities on Santa Cruz Island are currently in. An accidental fire could lead to the elimination of certain species from a particular plant community and a loss in native species richness. The resulting 'gaps' in the community could allow for increased invasion by non-native plant species.

Once all the feral pigs are removed from the island, the long-term effects to the native island flora are likely to be beneficial and substantial. Because they will no longer be preferentially consumed, native plants should be able to compete better with non-native plant species. The lack of disturbance patches caused by feral pig rooting, wallowing, and bedding, and the removal of pigs as a vector for the transport of weedy plant seeds should significantly slow the spread of non-native, invasive plant species. Certain island plant communities such as chaparral, grassland, riparian zones, and oak woodland would likely benefit the most with the removal of feral pigs since they are the communities being the most impacted. Seeds, berries, and acorns produced in these communities, and now actively consumed by feral pigs, would be stored in the soil for natural disturbance episodes or available for seedling generation in open available habitat. The native, island flora would return to a more natural composition, and the cover and frequency of native plants should increase. This has been demonstrated within the Park on Anacapa, Santa Barbara, and San Miguel Islands. The native vegetation on those islands had been devastated by introduced herbivores such as rabbits, goats, burros, and sheep (Sauer 1988). Today, after the removal of all the non-native herbivores from those islands, the native vegetation has flourished and occupies much of its former extent (Sauer 1988; data on file, Channel Islands NP).

Litter retention, although no doubt improving with the removal of feral sheep, would be further enhanced with the removal of feral pigs. The increase in litter retention would lead to a reduction in soil erosion to more "natural" levels. The soil micro-flora and fauna, now confined to limited undisturbed areas should be able to re-

colonize those areas where they have been eliminated.

Cumulative Effects

Cumulative effects to plant communities would be similar to those described under Alternative One. Future activities for TNC, as described earlier, include allowing a one-time pig hunt conducted under California Department of Fish and Game regulations prior to implementation of pig eradication activities. Depending on the scope of this hunt, incremental effects may occur to native plant communities. Impacts associated with this hunt would be similar but magnified to those identified in Alternative Two for the professional hunting teams. These include increased trampling of vegetation, increased soil compaction and possible water run-off. There is also an increased risk of the introduction of non-native invasive plant species and the increased risk of an accidental fire.

Alternative Two will significantly decrease the cover and density of *Foeniculum vulgare* allowing forb species the ability to reestablish in fennel infested communities. Managers should be wary of increases in such noxious weeds as mentioned above (i.e. yellow star thistle), and if infestations begin to occur, immediate action should be taken to remove such invaders. Such noxious weeds can be as much of a problem, if not more, than fennel therefore the initial invasion stages should be contained before uncontainable infestations occur.

With the removal of both fennel and feral pigs, in an extremely short period of time, disturbance will decrease dramatically on the isthmus of Santa Cruz Island. With the removal of heavy disturbance, it is hopeful that ruderal (establishes following disturbance) invasive species will have a more difficult time invading native communities. There are unique opportunity for restoration, because fennel infested communities are surrounded by native plant species. These native plant communities (chaparral, oak woodland, coastal sage) produce a seedbank adjacent to the fennel-infested communities. Fruit-eating birds, insects, wind, and small mammals will carry seeds from the native communities into the fennel treated communities beginning the successional process in this now degraded landscape. Generally annual and perennial forbs are the first species to begin the successional process. As mentioned above, managers should be wary of the non-native annual and perennial forb species arriving first and blocking the successional process from occurring.

Alternative Two will eliminate pig disturbance within two years, eliminating the vector for Mediterranean annual grass invasion. Feral pig removal will eliminate the last remaining feral quadrupeds, animals that are known to facilitate the spread of such weedy species. Native perennial bunch grasses are often in direct competition with Mediterranean annual grasses; therefore the decrease in vectors of spread for Mediterranean annual grasses may facilitate the recovery of native perennial bunch grasses. However, full recovery and establishment of these species may require out-planting with plugs.

Alternative Two will result in a vigorous eradication of feral pigs from Santa Cruz Island. The removal of feral pigs will prevent the invasion of shrub communities by invasive species via disturbance. The lack of rooting in shrub communities may facilitate in the recovery of native shrub species. The lack of disturbance will allow natural regeneration of shrubs via germination of seeds beneath the shrub canopies. This regeneration may also lead to the encroachment of shrubs into the degraded fennel/treated community, and the continued recovery of other disturbed communities throughout Santa Cruz Island.

Threatened and Endangered Plant Species

Effects of Implementing Fennel Control

Fire and herbicide effects would be the same for Alternatives Two, Three, and Four.

Fire effects on T&E species

The only threatened and endangered species currently known in the isthmus treatment area is *Galium buxifolium* or Sea-cliff bedstraw (U.S. Fish and Wildlife Service 1999). *Galium buxifolium* is a dioecious woody shrub in the Rubiaceae family that grows on coastal bluffs and north-facing sea cliffs. Associated native shrub species with *G. buxifolium* are *Artemesia californica*, (Coastal sagebrush) *Coreopsis gigantea*, (Giant coreopsis) *Eriogonum grande ssp. rubescens*, (Red buckwheat) and *Rhus integrifolia* (lemonade berry) among others (U.S. Fish and Wildlife Service 1999). Care should be taken not to burn the coastal bluffs containing this endangered species. If a spot fire occurs in the coastal bluff, it is possible that the *G. buxifolium* will recover, as its native woody species counterparts are able to recover from fire. Because little is known about the life history of this endangered species, fire should be avoided.

Herbicide effects on T&E species

Galium buxifolium is a dicot species that may be susceptible to death by Garlon 3A. Although other woody species found in the same plant community as the bedstraw are able to recover from the herbicide spray, all possible steps should be taken to avoid spraying the endangered plant. If the *Galium* is found in a highly fennel infested community, managers should spray the fennel infestations near the endangered species with backpack sprayers to avoid this endangered plant.

If fennel infestations are removed from *Galium* communities, more areas may open up for re-introduction of the native species via seed and plugs.

Effects of Implementing Pig Eradication:

The impacts and benefits associated with this alternative are likely to be similar to those for native plant communities except those associated with an accidental fire. In the case of a fire, the adverse impacts are likely to be more severe. A large fire could cause the extirpation of one or more rare plant occurrences. For the island endemic Santa Cruz Island fringepod any disturbance to its one know extant occurrence could lead to extinction.

T&E plant species should experience increased survivorship and seedling establishment and recruitment. T&E plant species are likely to benefit from decreased disturbance levels, increased litter retention, and re-development of the soil crusts. As T&E populations recover, they should be able to better withstand any subsequent natural disturbance events that may occur. Larger population numbers provide insurance against the loss of a few individuals and the formation of genetic bottlenecks. Replenishment of the seed bank - for those species that rely on natural disturbance events - means adequate seedling establishment and recruitment will occur when the next disturbance event hits.

An example of recovery by a rare plant species was demonstrated on Santa Barbara Island with the Santa Barbara live-forever (*Dudlyea traskiae*), a succulent perennial that is endemic to the island. Santa Barbara live-forever was considered extinct due to the presence of feral rabbits on the island, which had been brought to the island by military personnel during World War II. By 1955, the feral rabbit population on the island peaked at about 2,600. Around that time, the National Park Service began shooting the rabbits. By 1958, the rabbits were largely extirpated from the island and by 1974, Santa Barbara Island live-forever began to reappear in areas that had been largely denuded by the rabbits

(Sauer 1988). Today there are approximately 500 individuals of Santa Barbara Island live-forever.

For other species such as Santa Catalina mimulus (*Mimulus traskiae*), it may be too late. This species was only known from Santa Catalina Island and has not been seen for over 60 years.

Cumulative Effects

With the eradication of feral pigs, *Galium buxifolium* will have the ability to recover from pig grazing and rooting. *Galium's* location on extreme coastal bluffs slopes should not be negatively effected by the eradication process, because vehicles, hunters, and dogs will not be frequenting such areas during the eradication process.

Mitigation and Monitoring Recommendations

During the monitoring process (throughout and post pig eradication) if increases in non-native forb species and/or noxious invasive grasses are detected (above 15% cover) with the decrease in fennel, control methods should be taken immediately. Invasive forb species such as yellow star thistle have cost land managers across California millions of dollars to control. If a noxious weed such as yellow star thistle replaced fennel, it would defeat the objective of fennel control. Many Mediterranean annual grasses are ubiquitous to Santa Cruz Island and should be expected to move into fennel treated areas. It is the invasive grasses that are not ubiquitous such as *Phalaris sp.* that should be monitored and removed immediately if found in the fennel treated areas.

Native grasses, forbs, shrubs, and threatened and endangered species should be monitored, and if increases occur, those areas should be protected during the eradication process. Out-planting with native species should also be considered on the isthmus and other highly degraded areas of Santa Cruz Island once pig eradication has occurred. Out-planting will encourage native species recruitment through seed set of the out-planted species and recruitment of frugivorous birds (McDonnell and Stiles 1983). Planting native species will also protect degraded soils from further erosion and future invasion by fennel and other noxious weeds.

Fennel

Effects of Implementing Fennel Control

Fire Effects on Fennel

Direct and Indirect - Unless a fire has an extremely long residence time, the prescribed burn will not directly kill a significant portion of the fennel. Fire will consume the previous years' woody stalks and leaves. A fire with a long residence time and a lot of heat may kill a portion of the fennel plants (Fig 5- compare '97-pre-burn to '98-post-burn data). The prescribed burn will most likely not consume the fennel seedbank.

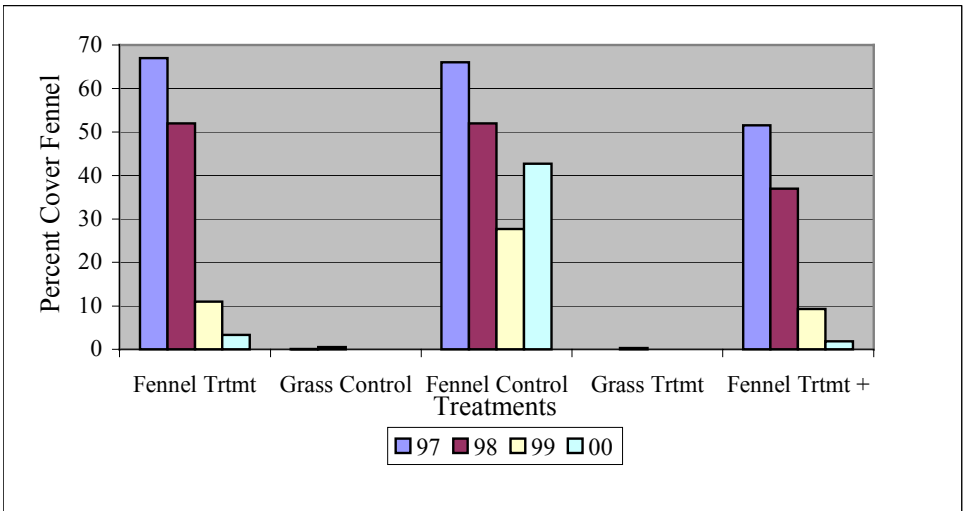
The prescribed burn will clear most of the fine fuels from the isthmus leaving bare disturbed areas of soil and gaps in the canopy. These types of soil and light conditions (open soil and more intense photon flux densities) are optimal for fennel seed germination; therefore the indirect effect of a prescribed burn may be the germination of many fennel seeds. The removal of dry fennel biomass will leave gaps in the fennel monoculture canopy as well, also producing optimal conditions for fennel seed germination. The removal of dead fennel biomass and the production of gaps around the individual fennel plants will increase the efficacy of the herbicide treatment because more fennel leaf surface area will be exposed to the herbicide.

Herbicide Effects on Fennel

Direct and Indirect - Garlon 3A is an auxin-type herbicide readily absorbed by both leaves and

roots of plants (Ahrens 1994). Once absorbed by the plant Garlon translocates through the symplast of plants and accumulates at the meristems. Symptoms of the herbicide include epinastic growth of the stems, leaves, and petioles, abnormal leaf shape and vein appearance, and swelling of the nodes. Death generally occurs within 3-5 weeks if death is going to occur. Because fennel is a perennial plant, plant death after one year of spray only occurs in approximately 50% of the plants (Erskine unpublished data).

Figure 5. The effect of an autumn burn and two subsequent spring sprays with Garlon 3A; Central Valley – Santa Cruz Island



Although fennel cover decreased by over 75% after the first spray in the Central Valley fennel project (Fig 5), fennel cover also decreased by nearly 50% in the untreated (fennel control) plots. The winter of 1998/1999 was a La Niña winter with very little rainfall. Subsequently, the minute amount of precipitation negatively affected fennel growth. From 1999 to 2000 fennel cover increased by nearly 50% in the fennel control plots. If the fennel treated plots were only sprayed once, there could have been a nearly 50% increase in fennel cover in the previously treated plots. Instead, the second spray decreased fennel cover by an additional 70-80% (Fig. 5).

Those fennel plants that survive the herbicide treatment have the ability to recover and set seed later the treated summer (Erskine personal observation). Of those plants that set seed, over 75% of the seeds produced from treated plants are viable (Erskine unpublished data). The greater the precipitation during the winter and spring, the greater the chance of fennel plant recovery. Because of the fluctuating environmental conditions, a minimum of two successive sprays is integral for fennel control. The first spray will thin out the expansive fennel stands making the second spray even more effective.

Cumulative Effects

Alternative Two includes fennel management and aggressive pig eradication. The fennel management strategy will decrease fennel cover facilitating hunters' abilities to eradicate pigs. The pig eradication will stop the disturbance that is rapidly promoting the spread of fennel across Santa Cruz Island. With the eradication of pigs, fennel control will be a feasible goal on the isthmus, and in other areas of Santa Cruz Island where pigs are spreading the noxious weed.

The aggressive control of fennel will initially cause increased disturbance via hunters, vehicles, and dogs throughout Santa Cruz Island. If measures are not taken to control the spread of fennel seeds during this period, fennel may spread to many previously uninvaded communities.

Mitigation and Monitoring Recommendations

Monitoring is a necessary mitigation measure for all aspects of the ecosystem and is therefore discussed at the end of the "Effects of Implementing Fennel Control" section. To avoid anthropogenic spread of fennel during the pig eradication process, vehicle-cleaning areas should be designated in each hunting zone. Vehicles, animals and shoes/clothing should be cleaned of fennel seeds daily in the "fennel cleaning areas." Vehicles/humans are vectors of fennel spread on Santa Cruz Island as can be seen on a majority of the Santa Cruz Island roads (Erskine personal observation). If seed control measures are not taken, the spread of fennel will occur in all hunted areas of Santa Cruz Island. Cleaning areas should be free of sensitive species, and fennel should be actively treated in these areas. This mitigation measure will decrease the spread of fennel, decreasing cover for feral pigs and decreasing negative soil effects from both pigs and fennel.

Other Weeds

Alternative Two

Effects of Implementing Fennel Control

Implementing fennel control will have limited benefit to decreasing other weed species on the island. The treatment areas proposed for fennel control are mostly monoculture stands. To decrease abundance of weeds other than fennel, separate management and control actions would need to be developed.

Effects of Implementing Pig Eradication

Cessation of soil and vegetation disturbance by pigs will immediately, rapidly, and steadily benefit all native plant species, as well as non-native species such as the large suite of annual grasses already present. These will provide rapidly-developing live and dead vegetation cover, which will prevent many seeds of invasive weeds from germinating. Since no alien plants are being controlled or restricted by pigs, cessation of pig impacts to soils and vegetation will not increase alien plant distributions or abundances.

Dispersal of weed seeds by pigs from infested to un-infested areas by will cease. Prevalence of favorable weed-seed germination conditions created by pig rooting and trailing will rapidly decrease.

Issue 3: Island Fauna Impacts

Native Island Fauna

Effects of Implementing Fennel Control

Effects for implementing fennel control on island fauna is the same for Alternatives Two, Three, and Four.

Fire Effects on Vertebrate Species

The prescribed burn should not directly affect birds, small mammals or the herpetofauna. A few small mammals may perish in the burn, if they live in the prescribed burn area, but the deceased should not significantly effect the population size.

The prescribed burn will thin the plant cover in the treatment area, which will decrease cover for small mammals and lizards. Plant community structure and composition are important components in the determination of lizard species diversity and abundance (Pianka 1966, Gibson 2000). Gibson (2000) found a decrease in Southern Alligator lizards (*Elgaria multicarinata)* and an increase in Side-blotch lizards (*Uta stansburiana*) after prescribed burning. *Elgaria* prefers cool humid environments (Kingsbury 1991), provided by fennel, and presumably relocates to these types of communities when the fennel is removed. Side-blotch lizards are "sit and wait" predators that exploit open spaces and ambush their insect prey when opportunity strikes

(Pianka 1966). Grasslands or more open structured, patchy communities are optimal for such foraging regimes. Prescribed burns leads to more open, patchy communities and will therefore favor *Uta* over *Elgaria*.

Herbicide effects on vertebrate species

Treatment with Garlon 3A will not directly effect lizards, birds or small mammals because in small concentrations, Garlon is not toxic to these creatures (Ahrens 1994). The reduction in fennel will accentuate the structural and compositional differences between fennel infested communities and fennel treated communities. This structure change will indirectly effect insectivorous birds and lizards because plant community structure effects invertebrate species (Thorpe unpublished data). As mentioned above, Alligator lizards prefer more cool and humid environments, therefore the abundance of Alligator lizards will decrease with the herbicide treatment because of the decrease in fennel cover (Gibson 2000). Side-blotch lizards should increase with the increase in patchiness of the community. Small mammals that rely on fennel for protection from predators may relocate to more dense-canopy communities such as the chaparral and will likely decrease in fennel treated areas.

Fire effects on Invertebrate Species

Fire should not directly effect the invertebrate species. The prescribed burn is expected to occur in October, when most invertebrate species are not present. The prescribed burn will indirectly effect invertebrate species the following spring by changing the structure of the isthmus plant communities. Those communities burned will have more gaps and slightly less vertical structure than the previous year. Because fennel and most shrub species resprout after burning, the vertical structure of the plant communities burned should not change significantly, and therefore the invertebrate species should not change significantly after a prescribed burn.

Herbicide effects on invertebrates

Garlon 3A should not directly effect the invertebrate species as it is an auxin-mimicking herbicide, and auxin is a hormone only found in plants. The lethal dose of Garlon for honeybees was found to be greater than 100µg/bee (Ahrens 1994), so those invertebrates that receive approximately 100µg of Garlon may perish.

The herbicide will indirectly effect invertebrate species by changing the structure of the isthmus plant communities. Those areas sprayed may have more gaps and less vertical structure than unsprayed communities (both native communities and fennel monoculture communities). Preliminary data indicate that fennel infested communities have over 15% more invertebrate families than grassland communities when comparing invertebrates attracted to aerial and ground yellow bowls, common invertebrate collection techniques (Thorpe unpublished data). Invertebrate species that prefer highly structured communities will likely move from fennel treated communities too more structured communities such as oak woodland and chaparral. Invertebrate species that prefer less vertically structured plant communities should increase the years following the Garlon spray.

Effects of Implementing Pig Eradication

Under this alternative, pigs would be removed from the islands in a two-year period. The removal of pigs overall would have very beneficial effects on island wildlife and fauna.

Removal of pigs would remove a direct mortality factor for invertebrates during certain times of year, since invertebrates are a part of the pig diet. Pigs would no longer adversely impact wildlife on Santa Cruz Island by destruction of suitable habitat. The cessation of pig rooting in specific locales would improve habitat for rodents, lizards, snakes, salamanders, foxes and skunks. Pig removal from riparian areas would improve riparian habitat for frogs, salamanders, and aquatic

invertebrates. The removal of pig rooting for acorns in years of significant mast would improve habitat for those species, such as the Santa Cruz Island jay, which depend upon mast crops.

Pig carcasses would no longer be a food source for ravens.

Removal of pigs would remove the primary prey base for non-native golden eagles. Pigs would no longer attract and support a breeding population of golden eagles on Santa Cruz Island. This would ensure that golden eagles would no longer be the primary mortality factors island fox populations on the northern Channel Islands further toward extinction.

Pig eradication actions themselves would have slightly negative impacts on island wildlife and fauna over the two-year removal period. The dog-hunter teams, which would necessarily traverse almost all areas of the island at least once, would have the following impacts. Dogs and hunters moving through the brush may encounter and inadvertently harass wildlife species such as island foxes and spotted skunks. Foxes in particular may react negatively to dogs. Foxes are likely to flee from dogs, and thus fox use of habitat and home ranges may be altered. It is unknown if these shifts in use would result in reduced fitness or survival of individual foxes.

Dogs used in the pig hunting will be vaccinated for common canine diseases, and that there will be no chance of transmission of such to the island fox population on Santa Cruz.

Cumulative Effects

Alternative Two, the control of fennel and the immediate eradication of feral pigs, will initially displace those species that utilize the structure of fennel. Chaparral, coastal sage and oak woodlands, all structurally diverse communities surround the fennel stands on the isthmus. Those species displaced by the removal of fennel will return to the native plant communities that they originally foraged in or inhabited. The removal of feral pigs will possibly allow for the succession of such native, structurally diverse communities into the previously fennel-infested areas. The reintroduction of native plant species will initially attract invertebrate species that prefer structurally rich communities, which will further relocate those vertebrate species originally displaced with the removal of fennel. Species that prefer the less structurally diverse grassland communities will use the fennel treated areas that are dominated by annual and perennial grasses.

Alternative Two, the control of fennel and the immediate eradication of feral pigs, will initially displace those invertebrate species that utilize the structure of fennel. Chaparral, coastal sage and oak woodlands, all structurally diverse communities surround the fennel stands on the isthmus. Those species displaced by the removal of fennel will return to the native plant communities that they originally foraged in or inhabited. The removal of feral pigs will possibly allow for the succession of such native, structurally diverse communities into the previously fennel-infested areas.

Those invertebrate species that prefer vertically simple plant communities will initially benefit from fennel control and pig eradication. As successional processes proceed, their habitats will decrease, and they will have to relocate to other grassland areas.

Other management actions for natural resources on Santa Cruz Island will have effects on island fauna, particularly island foxes. Golden eagles are currently being relocated from Santa Cruz Island, and probably will be on an annual basis until pigs are removed from the island. Relocation of golden eagles from the island will increase survivorship of island foxes on Santa Cruz Island. Moreover, if a funding source is found, bald eagles may be released on Santa Cruz Island within the next several years. If bald eagles attempt to breed on the island, their territorial nature may discourage golden eagle use of the island, thus decreasing golden eagle predation of island foxes. These positive effects on fox

survivorship would continue until pigs are remove. The removal of pigs would have positive effects on fox survivorship outweighing those of either golden eagle removal or bald eagle introduction. Without a feral pigs prey base, golden eagle use of Santa Cruz Island should be minimal.

Non-native Fauna (Pigs)

Effects of Implementing Fennel Control

The current large fennel stands on Santa Cruz Island impede successful hunting of pigs within them. Treatment of these fennel stands with the methods described in Chapter Two would decrease fennel cover enough to allow successful pig hunting operations to occur.

Effects of Implementing Pig Eradication

Under this alternative, the entire pig population, estimated at approximately 3,000-5,000 individuals, would be removed over a two-year period. Pigs would be killed either by live-trapping and then shooting with a handgun, or by hunting with dog teams and shooting.

Issue 4: Impacts to Physical Resources including Soils, Water and Air Quality

Effects of Implementing Fennel Control (Alts Two-Four)

Fire Effects on Soils

Direct and Indirect - Fire converts a portion of the organic carbon from a system into CO_2 and CO during a fire. Fire also converts a large portion of the plant material into nutrient-rich ash. Nutrients are lost from the system as both gas and particles of smoke. Portions of the soil N and S are released as N_2 and SO_2 gas. Fire increases extractable P and the rate of nitrification. Fire decreases organic P, phosphotase activity, and total soil N (Schlesinger 1997). Generally grassland fires do not heat up the soil to the point of soil sterilization (killing soil microbes).

With the accumulation of ash on the soil surface, there is an increase in nutrient availability. Ash also increases the availability of cations and P in the soil, and increases soil pH. Increased nitrification rates because of fire result in the loss of NO and N_2O, and the increased availability of NH_4^+ and NO_3^- (Schlesinger 1997). The removal of vegetation from soil via fire can indirectly effect the soil by increasing the possibility of run-off and erosion, especially with heavy rain and lack of vegetation after a fire.

Herbicide Effects on soil

Direct and Indirect - Garlon 3A (active ingredient Triclopyr) does not strongly adsorb to the soil. Garlon is rapidly degraded by microbes and by photolysis in water, with a half-life of 10 hours at 25ºC (Ahrens1994). Garlon 3A's persistence in the soil is moderate, with a half life ranging from 10-46 days (averaging 30 days) depending on soil type. Garlon 3A is first converted to an acid, and then neutralized to a salt. Negligible amounts of Garlon 3A are lost to volatilization (Ahrens1994).

Garlon 3A is readily absorbed by both monocot and dicot, leaves and roots. Living monocots quickly metabolize Garlon and are unaffected by the herbicide while dicots are killed. Microorganisms and weather conditions will degrade those plants killed by the herbicide releasing previously plant-bound nutrients into the soil. The herbicide treatment will also decrease the cover of fennel, which in turn will decrease cover for feral pigs, which should reduce the amount of rooting on the isthmus. The smaller fennel density will also lower the amount of fennel alkaloids secreted into the soil.

Air Quality Impacts (Alts Two –Four)

Air quality impacts would be similar for Alternatives Two, Three, and Four.

Smoke from prescribed fires is a complex mixture of carbon, tars, liquids, and different gases. This open combustion source produces particles of widely ranging size, depending to some extent on the rate of energy release of the fire. The major pollutants from wildland burning are particulate, carbon monoxide, and volatile organics. Nitrogen oxides are emitted at rates of from 1 to 4 g/kg burned, depending on combustion temperatures. Emissions of sulfur oxides are negligible.

Particulate matter is the term for solid or liquid particles found in the air. Some particles are large or dark enough to be seen, such as soot or smoke. Others are so small they can be detected only with an electron microscope. Breathing particulate matter can cause serious health problems. Particulates also reduce visibility in many parts of the U.S.

Most particulate emissions from prescribed burning (over 90 percent) are less than 10 microns (μ) in diameter (PM-10). This size particulate is considered to pose particular health concerns because PM-10 is small enough to enter the human respiratory system and has been linked with premature death, difficult breathing, aggravated asthma, increased hospital admissions and emergency room visits, and increased respiratory symptoms in children.

Fine particles also scatter and absorb light, creating a haze that limits our ability to see distant objects. Particle plumes of smoke, dust, and/or colored gases that are released to the air can generally be traced to local sources such as industrial facilities or agricultural burning. Regional haze is produced by many widely dispersed sources, reducing visibility over large areas that may include several states.

Haze from the fennel fire would not likely affect the visibility on the mainland given the distance smoke would have to travel to reach the mainland (25+ miles). For the same reason, smoke pollutants would not likely pose a health risk to the mainland population. However, given the prevailing winds, visitors on East Santa Cruz Island could be exposed to both haze and smoke.

Effects of Implementing Pig Eradication

Direct - Soil disturbing activities from pigs would be eliminated within three years of implementation of this alternative. Elimination would eventually allow disturbed areas to heal over with vegetation. No new pig rooting areas would be established. Activities associated with the eradication effort could cause localized erosion, especially in areas where new road or trails become established. If use of these trails and roads cease upon conclusion of the activities, the impacts would be short-term.

Indirect – Eventually, erosion from already disturbed sites would decline as the sites establish vegetation cover. As vegetation cover increases, overall watershed conditions would continue to improve. As watershed conditions improve, runoff within the watershed would be more readily intercepted by vegetation and be absorbed on site. This would cause less intense runoff events and decrease the rate of gully erosion (aggredation and widening). Less intense runoff events would cause less sediment delivery into local waterways.

Pig carcasses can impact water quality depending on the number (mass) of dead animals in a given location, decomposition rate, distance to live water, and distance to groundwater.

Dead pig carcasses can release into its surroundings a whole host of water quality affecting compounds including: Nitrates, TDS (total dissolved solids), chloride, and ammonium-nitrogen. The rate of these releases is dependent on the decomposing environment. For instance, in

anaerobic conditions (like underwater or extremely moist soil conditions) carcass decay is very slow. Release of these compounds off of the carcass would be prolonged with elevated concentrations above EPA standards. In contrast, in well-drained conditions a carcass can decompose fairly rapidly, with little or no effect on groundwater.

To keep concentrations of the above compounds at near normal ranges would require dead carcasses not be left in or near live water sources, or in shallow groundwater areas with poorly drained soils.

Cumulative Effects

Under this alternative fennel management will occur in conjunction with aggressive pig eradication. The burn and first of two sprays will occur before pig eradication begins, reducing the fennel cover and density to facilitate the hunting procedure. The two to three year time period for pig eradication will decrease the duration of pig rooting on the isthmus. Soil compaction will likely occur by the trampling of hunters and dogs, but the relatively short time period of this disturbance and the removal of pigs and pig-rooting disturbance will negate the compaction. The removal of pigs will decrease soil erosion by eliminating pig rooting, and by allowing plant species recovery in previously rooted areas.

Issue 5: Socioeconomic Factors including Cultural Resources and Human Uses

Cultural Resources

Effects of Implementing Fennel Control

Controlled burning of the fennel stands to reduce vegetation density for hunting creates the most potential for harm to cultural resources under this alternative. Within the fennel-vegetated areas are archeological sites and burials, as well as fences and other features related to the island's historic ranching operations. All of these resources are susceptible to damage or destruction by fire, cutting of fire lines, consequent vehicle and foot traffic and staging. Adverse effects of these activities can be avoided or mitigated through surveying the areas for historic and archeological resources, hand-cutting vegetation on and around these resources, and establishing fire lines, roads and staging areas with assistance of an archeological monitor.

Effects of Implementing Pig Eradication

This alternative would result in the most rapid eradication of pigs and therefore the least damage to cultural resources through continued pig depredations on archeological sites. The integrity of the island's National Register-listed archeological district has already been compromised to a great degree by pig rooting through disturbance of anywhere from 25 to 100 percent of many of the island's archeological sites, including ancient burials.

Feral pigs would continue to disturb archeological sites and burials on the island until the hunting activity was completed. Pig rooting is currently estimated to have damaged nearly all of the archeological sites on the island, to a minor or major extent. Pig rooting to a depth of three feet has been noted in a number of sites, particularly in areas covered by fennel or wild cucumber (Don Morris and Dr. Jeanne Arnold, personal communications). The information potential of some shallow sites and surface scatters has been completely destroyed by pig rooting. Rooting in the upper layers of deeper, more complex, stratified sites profoundly disturbs time and spatial relationships and destroys the context of the information contained in these sites.

During the hunting period, NPS would continue to try to protect the archeological record by fencing a small number of sites each year, as

funds allow, and to monitor the fenced sites to ensure that they remain pig-free. Once the pig eradication was completed, the fences would be removed.

Impacts to the island's cultural resources by the hunting operations are anticipated to be minimal and would primarily take the form of vehicle and foot traffic over archeological sites. Impacts of this nature could be minimized by orienting the hunting groups to the sensitivity of these sites to damage and requesting that they avoid traffic over them whenever possible. Campsites and trap locations could be cleared in advance for any cultural resources concerns.

Human Uses

The proposed action to conduct simultaneous island-wide eradication of pigs would have some short-term negative impacts on socioeconomic issues but would also have long-term positive impacts on the visitor experience. Visitor use would be restricted on NPS lands when hunting operations are occurring. Under this alternative island-wide eradication would be an intense effort over a short period of time 2-3 years. Depending on the operation that is being planned, during the three years of intensive hunting effort, NPS lands could be closed to visitation by visitors and researchers at any time during this period.

The annual visitation to Santa Cruz Island averages approximately 18,000 visitors per year. Depending on when and for how long the closure is in place, a portion of these annual visitors could be denied access to the island.

Alternative Three: Eradicate Pigs on NPS Property; Control Pigs and Protect Selected Sensitive Resources on TNC Property

Issue 1: Likelihood of Achieving Success

Effects of Implementing Fennel Control

Fennel control objectives would be realized under this alternative.

Effects of Implementing Pig Eradication

Direct and Indirect - Short-term eradication of pigs may be accomplished on NPS property, however, maintaining a pig free zone would be difficult to sustain over time. Relying on NPS personnel to continually maintain pig fence in a marine environment, monitor for pig sign, and then ultimately hunt pigs is costly and difficult to sustain over an extended length of time. Keeping the "pig free zone" free of pigs is possible for a short duration (1-2 years), however, has a very low likelihood of success in the long-term.

Issue 2: Vegetation Impacts

Native Communities

Effects of Implementing Fennel Control

Same as Alt.Two (See Alt. Two)

Pig Control Effects

Under this alternative, a pig proof fence would be constructed on the boundary between

NPS on Santa Cruz Island and TNC owned land on Santa Cruz Island. The feral pigs would then be eradicated from the NPS portion of the island. Within the TNC portion of the island, known sensitive plant resources would be fenced off and the feral pig population managed in perpetuity. The large stands of fennel on the isthmus would be prescribed burned followed by applications of the herbicide Garlon.

Direct, indirect, and Cumulative Impact - Under this alternative, native island plant communities within the NPS boundary would be protected but those on TNC property (approximately 76% of the island) would be subject to direct and indirect impacts associated with the presence of feral pigs as discussed under Alternative One.

Cumulative Effects

Most activities that are considered for cumulative impacts occur on both NPS and TNC lands except for those public recreation activities that do not occur on the TNC portion of the island. Research activities occur on both TNC and NPS lands. Most research activities on TNC lands is conducted under the supervision of the University of California at Santa Barbara (UCSB). Past research activities on TNC property have included prescribed burning to restore native vegetation and applications of prescribed burning and herbiciding to study the control of fennel (*Foeniculum vulgare*).

Fennel management on pig eradication on NPS property will initially remove a large portion of the fennel, allowing for successional processes to proceed on the isthmus. With the sporadic invasion of the isthmus by feral pigs breaking through border fences, the likelihood of non-native forb invasion, as well as re-invasion by fennel, is high. Managers will have to monitor the isthmus regularly to insure the integrity of the isthmus not only for feral pigs, but also for native and rare species. If continuous monitoring does occur, and control methods are taken when weed infestations are found, native forb species may begin the successional process on the isthmus.

Without management on *TNC* property feral pigs will continue to degrade the landscape by causing erosion events through rooting, and spreading noxious weeds such as fennel (*Foeniculum vulgare*), yellow star thistle (*Centaurea solstitialis*), tocalote (*Centaurea melitensis*), and Brassica species.

As mentioned earlier, the isthmus will be the initial area of feral pig re-infestation if pigs are eradicated from only the NPS property on Santa Cruz Island. Feral pigs will not only facilitate re-establishment of fennel monocultures on park service land, but will also increase the areas of disturbance for Mediterranean annual grass invasion. The initial fennel monoculture will decrease in cover and density after treatment, but may be replaced with Mediterranean annual grasses or re-infested with fennel if continued pig and invasive species/plant community monitoring does not occur. The strong possibility of feral pig entrance from *TNC* land makes it highly unlikely that fennel can be entirely eliminated from the isthmus and will make it difficult to control weeds in general.

The isthmus will be the initial area of feral pig re-infestation if pigs are only eradicated from the NPS property only on Santa Cruz Island. Feral pigs will not only re-root the fennel monocultures and treated areas on park service land, but will also root the native shrub communities producing gaps for Mediterranean annual grass and non-native forb invasion. The strong possibility of feral pig entrance from TNC land will decrease the possibility of native shrub invasion into the non-native fennel monocultures and the treated fennel areas unless continued monitoring occurs. With monitoring, native shrubs may begin to regenerate via seeds on park service land.

Threatened and Endangered Plant Species

Effects of Implementing Fennel Control

Same as Alt. Two (See Alt. Two Discussion)

Effects of Implementing Pig Eradication

Under this alternative, T&E plant occurrences would be protected to various extents on NPS and TNC property on Santa Cruz Island. Those occurrences on NPS property would be relieved of pig impacts and be able to expand beyond their current locations, as feral pigs would not be present on that portion of the island. Expansion of rare species into existing unoccupied habitat provides some measure of protection against extinction from random stochastic events. Expansion of listed species into unoccupied suitable habitat is an integral part of the draft recovery plan for these species (USFWS 1999).

The occurrences on TNC property however would be limited to their present locations, as feral pigs would have access to any current unoccupied habitat for those species. Without the possibility of expanding their number of occurrences these species would be at greater risk of extinction from random stochastic events.

Because the T&E plant occurrences on TNC property may be fenced, they would theoretically be free from direct predation by feral pigs. However, feral pigs are notorious for undermining fencing on Santa Cruz Island (Aschehoug, personal communication) and in order for the fencing to be effective, it would have to be constantly maintained. It is unlikely that the commitment of resources necessary for this type of maintenance is possible over the long-term and it is likely that some of the fencing would be breached in the future, allowing for direct predation on some of the "protected" T&E occurrences. For those occurrences, the T&E plants would be subject to the direct impacts associated with the presence of feral pigs, as listed under Alternative One.

While possibly initially free from direct predation, the T&E species on TNC property would still be subject to all of the indirect impacts associated with the presence of feral pigs, as listed under Alternative One.

There are seven known occurrences of listed plant species on NPS property – 5 occurrences of island rush-rose (*H. greenei*), 1 occurrence of island malacothrix (*M. squalida*, and 1 occurrence of island bedstraw (*G. buxifolium*). There are 28 known occurrences of listed plant species on TNC property. The occurrences are as follows: One occurrence of (*D. nesiotica*); eight occurrences of island bedstraw (*G. buxifolium*); three occurrences of island barberry (*B. pinnata ssp. insularis*); one occurrence of Santa Cruz Island malacothrix (*M. indecora*); three occurrences of Santa Cruz Island bushmallow (*M. fasciculatus v. nesioticus*); one occurrence of Santa Cruz Island fringepod (*Thysanocarpus conchuliferus*); three occurrences of Hoffman's rockcress (*Arabis hoffmanii*); and eight occurrences of island rush-rose (*Helianthemum greenei*) (USFWS 1999).

Cumulative Effects

Pig eradication on NPS property should encourage the survival and regrowth of *Galium buxifolium*. Escaped feral pigs from TNC property may graze on the *Galium* if they break through the property fence; therefore regular fenceline surveys should be done to ensure T&E species are protected from feral pigs.

Fennel

Effects of Implementing Fennel Control (including fire and herbicide treatments)

The methods proposed for controlling fennel is the same for Alternatives Two-Four. The effects of implementing fennel control on the target species is described under Alternative Two.

Cumulative Effects

As mentioned earlier, the isthmus will be the initial area of feral pig re-infestation if pigs are eradicated from only the NPS property of Santa Cruz Island. Feral pigs will not only re-root the fennel infestations on park service land, but the pigs will also bring in fennel seeds from TNC land via hooves and fecal matter. The initial fennel infestation will decrease in cover and density, with the initial fennel treatment, and with continued monitoring and control of outlier populations can possibly be controlled. The strong possibility of feral pig entrance from TNC land makes it highly unlikely that fennel can ever be entirely eliminated from the isthmus, and without constant monitoring and intervention, this area would return to the original infestation level. Without feral pig control, fennel will continue to spread on TNC property.

Other Weeds

Effects of Implementing Fennel Control

Same as Alternative Two (See Alternative Two)

Effects of Implementing Pig Eradication

NPS lands would be pig free under this alternative and would have similar benefits as described under Alternative Two. Valuable natural areas not deemed 'sensitive' enough to warrant fencing would continue to suffer severe and permanent depredation of native vegetation and increased weed presence and importance. The continued presence and activities of pigs over most of the island would continue to degrade island vegetation by further dispersal and establishment of invasive alien plants. Currently weed-infested areas would increase in size and weed population density. Areas not currently weed-infested would become so. Overall, recovery and development of native island vegetation would be hampered, and in some places, permanently damaged. Distributions and abundance of most alien plants would continue to increase.

Issue 3: Island Fauna Impacts

Native Island Fauna

Effects of Implementing Fennel Control

Same as Alt Two (See Discussion Alt. Two)

Effects of Implementing Pig Eradication

Under this alternative, the effects of full eradication mentioned above would apply to NPS lands, or those east of the isthmus boundary. Wildlife in those areas would reap the benefits of full removal, and be subject to the temporary negative effects of dog-hunter teams on the ground during eradication. Those effects of the eradication actions would also be seen in those areas on TNC lands slated for control efforts. Thus the effects would be the same at a much smaller scale.

Effects on island foxes may be negative, overall. Under this alternative, pigs would remain on central and west Santa Cruz, excluded on only selected sensitive resource areas. Thus, the pigs left on the island may still attract and maintain roosting, wintering or breeding golden eagles, which in turn would prey on foxes and skunks when piglets aren't in season. Retention of feral pigs on Santa Cruz Island may thus retard recovery of island fox populations on the northern Channel Islands.

Cumulative Effects

Alternative Three, the control of fennel and the eradication of feral pigs from NPS property only, would initially reduce fennel cover

displacing those species that utilize the structure of fennel. Chaparral, coastal sage and oak woodlands, all structurally diverse communities surround the fennel stands on the isthmus. Those species displaced by the removal of fennel would return to the native plant communities that they originally foraged in or inhabited. The removal of feral pigs would possibly allow for the succession of such native, structurally diverse communities into the previously fennel-infested areas.

If continued disturbance from "escaped" feral pigs occur; woodland recovery is highly unlikely. The burn and spray treatment would not kill all fennel, and the remaining fennel would likely spread into previously treated areas if pig disturbance occurs and further fennel control is not taken. Native vertebrates can continue to use these patches of dense fennel on the isthmus for foraging cover and habitat.

Alternative Three, the control of fennel and the eradication of feral pigs from NPS property only, would initially reduce fennel cover displacing those species that utilize the structure of fennel. Chaparral, coastal sage and oak woodlands, all structurally diverse communities, surround the fennel stands on the isthmus. Those species displaced by the removal of fennel would return to the native plant communities that they originally foraged in or inhabited. The removal of feral pigs would possibly allow for the succession of such native, structurally diverse communities into the previously fennel-infested areas if continued disturbance from escaped feral pigs occurs, succession is highly unlikely. More likely, there would be a mosaic of patches of dense fennel, and structurally rich native communities on the isthmus that some native invertebrates can use as habitat, and grassland communities for those invertebrates that prefer structurally simple communities.

Other management actions for natural resources on Santa Cruz Island will have effects on island fauna, particularly island foxes. Golden eagles are currently being relocated from Santa Cruz Island, and probably will be on an annual basis until pigs are removed from the island. Relocation of golden eagles from the island will increase survivorship of island foxes on Santa Cruz Island. Moreover, if a funding source is found, bald eagles may be released on Santa Cruz Island within the next several years. If bald eagles attempt to breed on the island, their territorial nature may discourage golden eagle use of the island, thus decreasing golden eagle predation of island foxes. These positive effects on fox survivorship would continue for the life of those individual programs. But without complete removal of pigs from the island, there will still be a prey base to support golden eagles.

Non-native Fauna (Pigs)

Effects of Implementing Fennel Control

Same as Alternative Two

Effects of Implementing Pig Eradication

On NPS property and in control zones on TNC property, pigs would be killed using the same methods as in Alternative Two.

Issue 4: Impacts to Physical Resources including Soils, Water and Air Quality

Effects of Implementing Fennel Control

Fire Effects

Same as Alt. Two.

Herbicide Effects

Same as Alt. Two

Effects of Implementing Pig Eradication

Direct and Indirect – Pig exclusion on TNC owned lands to cultural and sensitive resource sites would not abate pig rooting over the majority of TNC owned lands. Pig rooting, and the resulting erosion would continue to occur. Impacts of pigs on TNC owned lands would have similar effects as described in Alternative One.

Impacts from pig rooting would cease on NPS owned lands and watersheds within this area would begin to heal. The expected watershed level beneficial impacts would be similar as described under Alternative Two.

Pig carcasses can impact water quality depending on the number (mass) of dead animals in a given location, decomposition rate, distance to live water, and distance to groundwater.

Dead pig carcasses can release into its surroundings a whole host of water quality affecting compounds including: Nitrates, TDS (total dissolved solids), chloride, and ammonium-nitrogen. The rate of these releases is dependent on the decomposing environment. For instance, in anaerobic conditions (like underwater or extremely moist soil conditions) carcass decay is very slow. Release of these compounds off of the carcass would be prolonged with elevated concentrations above EPA standards. In contrast, in well-drained conditions a carcass can decompose fairly rapidly, with little or no effect on groundwater.

To keep concentrations of the above compounds at near normal ranges would be to avoid dead carcasses in or near live water sources, or in shallow groundwater areas with poorly drained soils.

Cumulative Effects

Alternative Three would have much the same results as Alternative Two in the lands where fennel is treated. The isthmus is on the border of TNC/NPS properties, and if pigs were to break through pig proof fences into NPS land, the isthmus would be the first NPS property negatively affected by the feral pigs. Therefore the isthmus may continue to lose soil via erosion each time a feral pig escapes from TNC land and roots NPS land.

TNC soils would continue to be degraded through pig rooting. Pig rooting would erode soils and spread fennel in the disturbed areas. The spread of fennel could in turn lead to the accumulation of fennel secondary compounds in TNC soil, which may make revegetation with native plant species difficult.

Issue 5: Socioeconomic Factors including Cultural Resources and Human Uses

Cultural Resources

Effects of Implementing Fennel Control

Same as Alternative Two (See "Effects to Implementing Fennel Control on Cultural Resources")

Effects of Implementing Pig Eradication

Under this alternative, damage to archeological sites by feral pigs would continue essentially unabated on TNC property. Continued pig rooting of archeological sites on that portion of the island would result in their loss of integrity, and ultimately loss of the values which make the Santa Cruz Island archeological district eligible for the National Register of Historic Places. Pigs could be more rapidly eradicated on the National Park Service property than an island-wide eradication project, thus bringing to a rapid halt the continued damage to sites on the NPS portion of the island.

Pig rooting is currently estimated to have damaged nearly all of the archeological sites on the island, to a minor or major extent. Pig rooting

to a depth of three feet has been noted in a number of sites, particularly in areas covered by fennel or wild cucumber (Don Morris and Dr. Jeanne Arnold, personal communications). The information potential of some shallow sites and surface scatters has been completely destroyed by pig rooting. Rooting in the upper layers of deeper, more complex, stratified sites profoundly disturbs time and spatial relationships and destroys the context of the information contained in these sites. In addition, pig rooting has disturbed ancient burials found in many locations on the island.

NPS would continue to try to prevent complete loss of the archeological record by fencing a small number of sites each year, as funds allow. This, however, is a costly alternative that preserves only a small number of sites and requires constant monitoring to ensure that the fences are adequately keeping out the pigs. This alternative also does not preserve the archeological values for which the island was listed on the National Register.

The Santa Cruz Island archeological district is significant for the large number and diversity of pristine sites found on the island. Sites range from isolated artifacts to huge, stratified sites encompassing habitation areas and specialized activity areas spanning a period of 8,000-9,000 years. Continued pig depredations on TNC land, with small-scale efforts to fence and protect sites would result in a truncated archeological database. The number and diversity of sites would be greatly reduced, destroying the values of the district, and resulting in alteration of the boundaries of the National Register district. This perhaps may result in the NPS portion of the island retaining sufficient integrity to remain an eligible archeological district and leaving a small number of individually eligible sites on the TNC property. The value of remaining archeological sites would be greatly reduced, and future researchers would be unable to take advantage of new research techniques that may be developed in the future.

Impacts to the island's cultural resources by the hunting operations are anticipated to be minimal and would primarily take the form of vehicle and foot traffic over archeological sites. Impacts of this nature could be minimized by orienting the hunting groups to the sensitivity of these sites to damage and requesting that they avoid traffic over them whenever possible. Campsites and trap locations could be cleared in advance for any cultural resources concerns.

Controlled burning of the fennel stands to reduce vegetation density for hunting creates potential for harm to cultural resources under this alternative. Within the fennel-vegetated areas are archeological sites and burials, as well as fences and other features related to the island's historic ranching operations. All of these resources are susceptible to damage or destruction by fire, cutting of fire lines, consequent vehicle and foot traffic and staging. Adverse effects of these activities can be avoided or mitigated through surveying the areas for historic and archeological resources, hand-cutting vegetation on and around these resources, and establishing fire lines, roads and staging areas with assistance of an archeological monitor.

Human Uses

Impacts to visitors under this alternative would be similar to impacts under the proposed action, because pigs would still be hunted on NPS lands, where most visitation occurs. Additionally, some impacts on the visitor experience would be annual and recurring, since NPS would be in the position of defending a fenced boundary against invasion by pigs. Thus, annual trapping and/or hunting would occur on NPS lands near the isthmus boundary with TNC.

Impacts on researchers would be less under this alternative than under the proposed action. Island-wide eradication under the proposed actions would affect researchers in all parts of Santa Cruz Island, but the targeted control around sensitive resources on TNC lands would not have

the pervasive effects on island use that the proposed action would have.

Alternative Four: Sequential, Island-wide Eradication by Fenced Zone Hunting

Issue 1: Likelihood of Achieving Success

Effects of Implementing Fennel Control

Fennel control objectives would be realized under this alternative.

Pig Control Effects

Direct and Indirect - Like Alternative Two, the zone hunting strategy has a high likelihood of success. However, in contrast to Alt. Two, requirements for implementation are different in resource (personnel and budget) allocation in both extent and duration. Under the hunting zone strategy, resources are focused on one zone, rather than island-wide. Intensive hunting efforts would still occur within a zone, however, hunting would only be occurring in one zone at a time.

The infrastructure necessary to maintain an intense effort in a zone is much less than what is necessary for an island-wide effort. Because hunting would only occur sequentially, a zone at a time, the time needed (duration) to eradicate island-wide is increased.

Issue 2: Vegetation Impacts

Native Communities

Effects of Implementing Fennel Control

Same as Alternative Two.

Effects of Implementing Pig Eradication Activities

Under this alternative, Santa Cruz Island would be fenced off into six zones. Hunting teams would concentrate efforts into one zone at a time. Only upon complete removal of pigs from the zone would the hunting team move to the next zone in the eradication sequence. Periodic follow-up monitoring within the completed zone would be required to ensure it remains pig-free. Each zone would be eradicated of pigs by hunting teams. Hunting teams would consist of professional pig hunters and hunting dogs. This alternative would require approximately 40+ miles of fence and one team of hunters with dogs.

This process would take longer (6 yrs. vs 2 yrs) than that under the island-wide eradication alternative but the annual cost would be lower. The large stands of fennel on the isthmus would also be treated with prescribed burning and application of the herbicide Garlon under this alternative. Impacts to native flora and listed plant species would be similar to that under the island-wide eradication alternative with one important distinction. Installation and maintenance of the estimated 40+ miles of fencing needed could impact native island flora and listed plant species both directly and indirectly.

Direct and Indirect Impacts - Direct and indirect impacts to native, island plant communities would be similar to those described under Alternative Two although the beneficial effects would be delayed in those areas of the island that are not hunted free of pigs until the later sequential years. Additional short-term impacts would occur with the construction of the 40+ miles of fence line. Trampling and crushing of the island vegetation would occur and individual plants may be completely uprooted. Areas that are trampled bare, especially those on

steep slopes, may experience increased water run-off and soil loss during winter rain events. Gullies could form in some areas. In order for these fences to be effective in zoning the island, they would have to constantly be maintained. Feral pigs are notorious for undermining fencing systems and have repeatedly done so on Santa Cruz Island. The fencing system can only be maintained by repeated walking and checking of the fence line. Each time the fence line is checked would provide an opportunity for the seeds of invasive non-native plant species to be spread to various locations along the fence line. Removal of the pig zone fence would have similar direct and indirect effects as those associated with its construction.

Cumulative Impacts:

The cumulative impacts of this alternative would be similar to those discussed under Alternative Two.

Pig eradication by island zone would allow for rooting disturbance to continue on the isthmus for up to four to five years following the initiation of the eradication procedure. During that time period, it is highly likely that fennel would continue to establish in areas of the isthmus that are disturbed by pigs. This disturbance regime would negatively effect native forb regeneration and would likely cause more soil erosion to occur, in turn allowing for other invasive species to spread onto the isthmus such as yellow star thistle, tocalote, and *Erodium sp.* Although this option would lead to the eventual eradication of feral pigs, it would also leave more degraded communities from five extra years of pig disturbance.

If invasive species infestations are controlled as they occur on the isthmus during and after the pig eradication process, native species succession may occur.

Alternative Four would lead to feral pig eradication from Santa Cruz Island in a minimum of six years. Pig eradication by island zone would allow for rooting disturbance to continue on the isthmus for this six-year period. Zones not yet hunted would continue to have pig disturbance, and zones that are completed or where the zones are currently undergoing eradication activities, would be subjected to disturbance pigs, hunters, dogs, vehicles and monitoring teams. This disturbance would create enough oases of disturbed soil to establish Mediterranean annual grasses, exotic forbs, as well as fennel from the seed bank in these disturbance gaps.

Mediterranean annual grasses have already begun to invade pristine native communities such as chaparral, coastal sage and oak woodlands. The four to five year disturbance regime likely to occur with Alternative Four would allow the continued invasion of non-native grasses into these native communities, and may type convert some of these communities (i.e. coastal sage) into Mediterranean annual grasslands. Although Alternative Four would lead to the eventual eradication of feral pigs, it may also leave an extremely degraded isthmus (and other island areas) containing many non-native species. Aggressive restoration techniques may be needed to facilitate the re-establishment of native shrub communities in areas of heavy invasive species infestations.

Mitigation and Monitoring Recommendations

Managers would have to monitor the isthmus regularly to insure the integrity of the isthmus not only for feral pigs, but also for native and rare species. If Mediterranean annual grasses infest the isthmus, it would be extremely difficult for successional processes to occur as Mediterranean grasses have been shown to inhibit the germination and growth of certain California native woody species (Eliason and Allen 1997). If continuous monitoring does occur, and control methods are taken when weed infestations are found, native species, including perennial bunch

grasses may begin the successional process on the isthmus.

Threatened and Endangered Plant Species

Effects of Implementing Fennel Control

Same as Alt Two (See Alt. Two discussion)

Effects of Implementing Pig Eradication

Direct Impacts - Direct impacts to listed plant species could occur if fencing were placed within listed plant occurrences. Individual plants could be crushed or uprooted when fence posts are placed in the ground. NPS employees could also inadvertently crush plants by walking or driving over them. This could occur when initially constructing the fence or during maintenance of the fence. With proper planning, known rare plant occurrences could be avoided and botanical surveys conducted to locate unknown rare plant occurrences so that they could also be avoided. However, botanical surveys can sometimes overlook TES plant occurrences. The accuracy of the survey depends on the timing (when the survey is conducted) and the familiarity of the surveyor with the plants in question. The possibility exists that even with botanical surveys being conducted that TES plant occurrences could be missed and subsequently impacted by the installation of the zoning fences. Until a zone is hunted free of pigs, any TES plant occurrences in the zone would be subject to the direct impacts associated with the presence of feral pigs as described under Alternative One. For those TES occurrences in the last zone to be hunted free of pigs, this would mean an additional six years of impacts associated with the presence of feral pigs.

Indirect Impacts - Indirect impacts to listed plants could occur if invasive non-native seeds are transported into listed plant occurrences either on the fencing material itself or on the boot and clothing of the NPS employees constructing the fence or on the vehicles used to move the fencing material. As discussed previously, invasive weed species are able to out-compete native plant species including TES plants for available water, nutrients, and sunlight. Measures such as washing vehicles, removing seeds from boots and clothing, and educating those involved in constructing the fences about the dangers of invasive weed species, can be enacted to minimize the risk of spreading these weed species. Until a zone is hunted free of pigs, any TES plant occurrences in the zone would be subject to the indirect impacts associated with the presence of feral pigs as described under Alternative One. For those TES occurrences in the last zone to be hunted free of pigs, this would mean an additional six years of impacts associated with the presence of feral pigs.

Cumulative Effects

Alternative Four leads to pig eradication after approximately six years of hunting. This extended period of time may be too long for the endangered species to survive, as the populations were extremely small as of the last surveying date (Hockberg *et.al.* 1980). Feral pigs have been known to graze and root *Galium buxifolium* (US Fish and Wildlife 1999). *G. buxifolium* populations should be surveyed before and during the eradication process so that the park service has an idea of the population's extent. If escaped pigs appear to be grazing or rooting the endangered species during the extended hunting period, exclosures should be considered around the surviving population to prevent the extermination of this endangered species. Once eradication has occurred, *Galium buxifolium* should begin to recover on the isthmus, and across Santa Cruz Island.

The cumulative impacts associated with this alternative would be similar to those discussed under Alternative Two.

Fennel

Effects of Implementing Fennel Control (including fire and herbicide treatments)

The methods proposed for controlling fennel is the same for Alternatives Two, Three, and Four. The effect of implementing fennel control on the target species is described under Alternative Two.

Cumulative Effects

Alternative Four would lead to feral pig eradication from Santa Cruz Island in a minimum of six years from the completion of phase one. Four to five years of feral pig rooting and disturbance by hunters, dogs, vehicles and monitoring teams would create enough oases of disturbed soil to establish new fennel plants from the seed bank, and establish new fennel communities along the isthmus, and throughout Santa Cruz Island. Fence building and pig rooting would create disturbances for the establishment and spread of fennel.

Because the isthmus would be one of the last zones eradicated of pigs, pig rooting and fennel invasion would continue on the isthmus for the next four years minimum. The continued spread of fennel on the east side of the island would make fennel control difficult when the management protocol is initiated pre-pig eradication. Fennel would likely spread in both density and cover in the more diverse dicot communities, which would make the herbicide spray more difficult. The difficulty in controlling fennel would decrease the efficiency of pig eradication on the isthmus, increasing anthropogenic disturbances and therefore increasing the number of areas for fennel invasion. Because of the ruderal nature of fennel seed germination, active monitoring and control are the only ways this invasive species would not re-establish under Alternative Four.

Mitigation and Monitoring Recommendations

See Alternative Two.

Other Weeds

Effects of Implementing Fennel Control

Same as Alternative Two (See Alternative Two).

Effects of Implementing Pig Eradication

Cessation of soil and vegetation disturbance by pigs would immediately, rapidly, and steadily benefit all native plant species in the section being cleared, as well as non-native species such as the large suite of annual grasses already present. These together would provide rapidly developing live and dead vegetation cover, which would prevent many seeds of invasive weeds from germinating. Since no alien plants are being controlled or restricted by pigs, cessation of pig impacts to soils and vegetation would not increase alien plant distributions or abundance.

Dispersal of weed seeds by pigs from infested areas within the area to un-infested sections would cease. Prevalence of favorable weed-seed germination conditions created by pig rooting and trailing would rapidly decrease.

Creation of access for delivery of fencing materials, equipment, and personnel would create weed-vulnerable openings in vegetation, and disturb soil. These impacts would facilitate weed seed dispersal and weed establishment, both during fence construction and for the length of the project, since fences would need to be frequently monitored and maintained. Pigs would adopt new access tracks and trails, and rapidly disperse weed seed along them into previously minimally impacted areas. Travel by hunters in and out along these routes and within and hunted areas would disperse seeds, as vehicles, boots, and equipment are transported between infested and uninfested areas. Impacts would continue after completion

of the project wherever road scars and weed populations have developed.

Overall effects of Alternative Four are similar to those described for Alternative Two, but since some areas would not be treated for several years, significant negative impacts to soils and vegetation would continue in these areas, and weed populations would continue to increase and spread. Long-term effects would be dramatically better than for Alternative Three, since the entire island would eventually be pig-free.

Cumulative Effects

Issue 3: Island Fauna Impacts

Native Island Fauna

Effects of Implementing Fennel Control

Same as Alt.Two (See discussion Alt.Two)

Effects of Implementing Pig Eradication

Building and maintaining 40+ miles of fence would have slight negative effects on wildlife and fauna. Movement of wildlife would generally not be affected by pig-proof fencing, except possibly to slow the movements of Island spotted skunks. Island foxes have great climbing ability and would not be affected by a fence.

Fence building itself could have temporary negative impacts, as presence and activities of fence builders may disturb wildlife. However, this is unlikely, since much fence will be along road or ridgelines with little cover and less chance of harboring wildlife at any particular time. It is assumed that little clearing of vegetation will occur during fence building.

During pig hunting, wildlife and fauna in the fenced zones would be subject to the same effects identified in Alternative Two. Those effects, generally, are significantly beneficial effects of pig removal, and slightly negative effects of removal actions themselves.

Cumulative Effects

Alternative Four, the control of fennel and the eradication of feral pigs by island zone, will allow for six years of additional disturbance in the last zone to be hunted. This extended disturbance regime will allow the continued spread of fennel in the remaining grassland areas of the isthmus. The spread of fennel will continue to displace those vertebrate species (i.e. *Uta*) which prefer less structurally diverse plant communities, and will increase the habitat of those vertebrates that prefer structurally diverse plant communities. With the treatment of fennel and the eradication of feral pigs, there will be an increase in structurally simple plant communities. Those vertebrate species displaced by fennel encroachment will relocate back into the structurally simple habitats.

Alternative Four, feral pig eradication by island zone, will allow for continued pig disturbance during the initial eradication process. Disturbance will allow fennel to continue spreading in disturbed sties, increasing habitat for invertebrate species that prefer structurally diverse communities, and decreasing habitat for those that prefer simple plant communities.

When the isthmus zone is treated and pig eradication occurs, it may be more difficult to control the expanded fennel. Post-treatment, the isthmus will likely be a patchy mosaic of grasslands, fennel stands and shrub stands. This diversity in plant communities, whether native or not, will provide habitat for both classes of invertebrate species leaving a zero net effect of treatment on invertebrates under Alternative Four.

Other management actions for natural resources on Santa Cruz Island will have effects on island fauna, particularly island foxes. Golden eagles are currently being relocated from Santa Cruz Island, and probably will be on an annual

basis until pigs are removed from the island. Relocation of golden eagles from the island will increase survivorship of island foxes on Santa Cruz Island. Moreover, if a funding source is found, bald eagles may be released on Santa Cruz Island within the next several years. If bald eagles attempt to breed on the island, their territorial nature may discourage golden eagle use of the island, thus decreasing golden eagle predation of island foxes. These positive effects on fox survivorship would continue until pigs are remove. The removal of pigs would have positive effects on fox survivorship outweighing those of either golden eagle removal or bald eagle introduction. Without a feral pigs prey base, golden eagle use of Santa Cruz Island should be minimal.

Non-native Fauna (Pigs)

Effects of Implementing Fennel Control

Same as Alternative Two.

Effects of Implementing Pig Eradication

In fenced units, pigs would be killed using the same methods as in Alternative Two.

Issue 4: Impacts to Physical Resources including Soils, Water and Air Quality

Effects of Implementing Fennel Control

Effects of fire on Soil Resources

Same as Alt. Two.

Effects of Herbicide on Soil Resources

Same as Alt. Two

Effects of Implementing Pig Eradication

Direct and Indirect – This alternative is similar to Alternative Two in that eventually pigs would be eradicated from the island. Beneficial impacts would eventually be realized as described under Alternative Two. The difference between the alternatives is the time delay in which the beneficial effects would be realized. Under Alternative Four, pig impacts would continue to occur in zones that have not been hunted.

This alternative has zones that are the most difficult to hunt being implemented first. The topographic relief and the amount of vegetation cover within the zone determined hunting difficulty. Since zones being hunted first have the greatest vegetation cover, they also have the best watershed conditions. The zones to be hunted last have poorer watershed conditions. These zones would have up to six years of continued pig disturbance prior to pig eradication.

Cumulative Effects

Alternative Four will eventually lead to pig-eradication and the end of pig-caused disturbance and erosion on Santa Cruz Island. Because the eradication process is expected to take four to five years, and fennel treatment will not occur until the end of the eradication process, erosion will continue to occur on the isthmus until the pigs are eradicated. The dense cover and density of fennel currently present on the isthmus will prevent some erosion by pig rooting, but the increased duration of fennel in these areas may increase the amount of secondary compounds left in the soil after fennel treatment. Studies have not been done on the duration of fennel secondary compounds in the soil.

Pig disturbance may increase on the isthmus during the eradication process, which may increase rooting, erosion and the spread of fennel. This will make fennel control more difficult and, in turn, pig eradication from the isthmus zone more difficult. The eventual eradication of pigs

from the isthmus will leave the isthmus in a degraded state with potentially large fennel stands and eroded soils which may decrease the ability of native species to re-establish.

Recommended Mitigation Alts Two-Four

It is likely that soil disturbance and erosion would occur as a result of new road and trail development, or more intensive use of already established roads and trails. It is likely that many of these localized disturbed sites may heal over time after operations cease. However, recovery of these sites would heal faster should active restoration techniques be implemented. Site restoration would occur under the direction of the Park's restoration biologist on NPS lands, and under the direction and discretion of the TNC on TNC owned lands. Site restoration may include, but not limited to erosion abatement, seeding, and planting.

Issue 5: Socioeconomic Factors including Cultural Resources and Human Uses

Cultural Resources

This alternative would result in archeological sites in different units being subjected to varying degrees of damage through continued pig depredations. The units in which pigs were hunted first would suffer the least; units in which pigs were hunted last would suffer the most. The amount of damage caused by pigs would decrease each year as units are hunted out and the overall number of pigs decreases.

The integrity of the island's National Register-listed archeological district has already been compromised to a great degree by pig rooting through disturbance of anywhere from 25 to 100 percent of many of the island's archeological sites, including ancient burials. Feral pigs would continue to disturb archeological sites and burials on the island until the hunting activity was completed. The length of time required to completely eradicate pigs will have a profound effect on the integrity of the island's archeological resources. Continuing damage to a large number of sites throughout the hunting period will result in the loss of significant scientific data. The archeological value of the sites will be reduced and future archeologists will be less able to take advantage of new technology that may be developed to investigate the island's archeology.

Pig rooting is currently estimated to have damaged nearly all of the archeological sites on the island, to a minor or major extent. Pig rooting to a depth of three feet has been noted in a number of sites, particularly in areas covered by fennel or wild cucumber (Don Morris and Dr. Jeanne Arnold, personal communications). The information potential of some shallow sites and surface scatters has been completely destroyed by pig rooting. Rooting in the upper layers of deeper, more complex, stratified sites profoundly disturbs time and spatial relationships and destroys the context of the information contained in these sites.

During the hunting period, NPS would continue to try to protect the archeological record by fencing a small number of sites each year, as funds allow, and to monitor the fenced sites to ensure that they remain pig-free. Once the pig eradication was completed, the fences would be removed.

The island-wide fencing program has the potential to adversely affect cultural resources. Desirable locations for placing fencing, such as broad ridges, are also likely locations of archeological sites. The fencing program also may conflict with the fence and pasture patterns established during the historic ranch period, requiring alteration or removal of some of these historic features. Damage to archeological sites and alteration or removal of historic features may be avoided by conducting a cultural resources survey of the proposed fence locations and placing

the fencing in areas where there will be no impacts on cultural resources.

Impacts to the island's cultural resources by the hunting operations are anticipated to be minimal and would primarily take the form of vehicle and foot traffic over archeological sites. Impacts of this nature could be minimized by orienting the hunting groups to the sensitivity of these sites to damage and requesting that they avoid traffic over them whenever possible. Campsites and trap locations could be cleared in advance for any cultural resources concerns.

Controlled burning of the fennel stands to reduce vegetation density for hunting creates the most potential for harm to cultural resources under this alternative. Within the fennel-vegetated areas are archeological sites and burials, as well as fences and other features related to the island's historic ranching operations. All of these resources are susceptible to damage or destruction by fire, cutting of fire lines, consequent vehicle and foot traffic and staging. Adverse effects of these activities can be avoided or mitigated through surveying the areas for historic and archeological resources, hand-cutting vegetation on and around these resources, and establishing fire lines, roads and staging areas with assistance of an archeological monitor.

Human Uses

Essentially the island will be divided into zones and sequentially trapped and hunted for pigs. While each zone is being hunted, impacts to the visitor experience in that zone will be substantial. For example boaters visiting specific anchorages on central and west SCI would not be permitted to come ashore while hunting operations are occurring. The isthmus and the east end will comprise one zone, and so effects to visitors coming ashore would be confined largely to this zone.

While the zone is hunted, visitor access to the zone will be reduced, if not eliminated altogether. Thus, the isthmus and east Santa Cruz may be closed to visitor use during pig hunting activities, thus preventing thousands of visitors from recreating on Santa Cruz Island for perhaps as long as six months or a year. The number affected on east Santa Cruz would be some portion of the 18,000 visitors that currently go ashore.

Access for researchers may also be reduced or eliminated during pig-hunting activities in a zone. Thus, up to 20 researchers per year may be prevented from completing a portion or all of their research projects on Santa Cruz Island.

Long-term positive effects on the visitor experience include the elimination of pigs and pig effects from the ecosystem of Santa Cruz Island.

Sustainability and Long Term Management

This section of the analysis will focus in on the relationship between local short-term uses of the environment and the maintenance and enhancement of long term productivity, irreversible and irretrievable commitments of resources, and adverse impacts that cannot be avoided. The analysis is divided into the no action alternative and the action alternatives (Alternatives Two-Four) since sustainability and long-term management consequences are similar across all action alternatives. The difference, if any would be the scale of impact to the resources.

The Relationship between Local Short-term uses of the Environment and the Maintenance and Enhancement of Long-Term Productivity

For any of the alternatives considered, no long-term management possibilities or park productivity of resources are being traded for the

use of NPS owned lands. Island-wide resource impacts would continue to occur if action is not taken on pigs on Santa Cruz Island. Future visitors to Santa Cruz Island could notice a change in the landscape (visual change in vegetation) with the removal of pigs from Santa Cruz Island. The action of eradicating pigs on Santa Cruz Island would be a sustainable action with favorable environmental consequences.

Irreversible and Irretrievable Commitments of Resources

No permanent or long-term (irreversible) commitment of environmental resources would result from implementing any of the action alternatives considered in this analysis. Restriction of visitor use is considered to be an irretrievable (short-term) loss. Visitor use must be restricted to ensure visitor safety to successfully complete the pig eradication.

The decision to not implement any action could result in some rare or endangered species to be adversely affected (extinction for example) in the long-term (irreversible).

In this analysis the Park determined that this analysis does not require analysis of energy requirements (1502.16), nor does it require an economic impact analysis (EO 11821).

Adverse Impacts that Cannot be Avoided Should the Action be Implemented

The action alternatives considered in this analysis do not result in impacts that cannot be fully mitigated or avoided.

Summary of Impacts by Alternative

For each alternative action, the Park analyzed the potential environmental impacts that would likely occur. Environmental impacts were divided into the following categories: Native Plant Communities, Rare and Listed Plants, Non-native Plants, Native Island Fauna, Non-native Island Fauna, Soil and Water Resources, Cultural Resources, and Human Uses.

The preferred alternative by the Park is Alternative Four: Sequential, Island-wide Eradication by Fenced Zone Hunting. Under this alternative there would be some short-term impacts to native flora, fauna, soils, waters, cultural resources, and human uses due to the activities associate with fennel control and feral pig eradication. However, following fennel control and eradication of feral pigs from a given zone, protection of irreplaceable island resources will be immediate and recovery of many impaired natural resources will begin immediately.

Table 7. Summary Table of Environmental Consequences

	Alternative One	Alternative Two	Alternative Three	Alternative Four
Likelihood of Success	Alternative One makes it impossible for the NPS to achieve its goals for conserving natural and cultural resources on SCI and restoring the natural ecosystems of the island. The facts that nine plant species from Santa Cruz Island have been listed as threatened or endangered and that island foxes have declined precipitously in recent years is an indication of the destruction of native resources caused by feral pigs. Feral pigs have irreversibly damaged numerous archeological sites.	Alternatives Two is an excellent strategy for protecting island resources but would be very difficult to achieve because of the need to fund and support a very large operation over a short period of time. Funding realities substantially lessen the "Likelihood of Success" for this alternative.	Alternative Three has a low "Likelihood of Success" because more than 2/3 of the island, containing extremely significant natural and cultural resources, would continue to be subjected to feral pig impacts. Additionally, it is expected that maintaining a pig-proof fence across the island will be expensive and an exercise in futility. Feral pigs would be able to go around the ends of the fence at low tide. Pigs are very adept at breaking through fences. It is doubtful that park personnel, with all the demands and issues they face, could sustain in perpetuity the effort necessary to hold a fenceline.	Alternative Four has the highest "Likelihood of Success" because it achieves the best balance of expeditiously and comprehensively protecting resources in a manner that the NPS is likely to be able to support financially and logistically. The longer time necessary to complete the project will allow more post-sheep vegetation recovery, increasing the difficulty of feral pig eradication and slightly reducing the "Likelihood of Success". Success is not guaranteed under this Alternative. Highly effective personnel and substantial funds will need to be dedicated to the project on a sustained basis to achieve success.
Native Plant Communities	Fennel will continue to spread, aided by rooting pigs. Pigs will continue impacts on vegetation through rooting, accelerated soil erosion, seed predation, carrying of weed seeds, and creation of trails.	Fennel burn will increase soil nutrients in the short term, and kill some native plants. Fire will stimulate seed germination of some native plants. Small patches of native plants and boundary areas may experience mortality due to herbicide effects. The control of fennel and eradication of feral pigs will have substantial and positive effects on native plant communities.	Effects from fennel burn and herbicide application same as Alternative Two. The control of fennel and eradication of feral pigs will have substantial and positive effects on native plant communities on approximately 24% of the island. Most of the island's native plant communities will be exposed to the feral pig impacts described in Alternative One.	The environmental consequences are substantially similar to Alternative Two. The primary difference is that the project will take approximately 5 years longer to complete and there will be impacts from fence building and removal. Effects from fennel burn and herbicide application same as Alternative Two. The control of fennel and eradication of feral pigs will have substantial and positive effects on native plant communities.

	Alternative One	Alternative Two	Alternative Three	Alternative Four
T & E Plant Species	The factors that led to the decline of rare and listed plants will largely continue. Feral sheep, which also contributed to rare plant declines, have been removed. However, feral pigs continue to impact almost all known populations of listed plant species.	One listed plant species, *Galium buxifolium*, occurs on the isthmus where the dense fennel occurs. However, the *Galium* does not co-occur with the fennel. No burning or herbicide is planned for the coastal bluff habitat inhabited by the *Galium* and no effect is anticipated. The nine listed plant species and numerous rare plants should all benefit from the eradication of feral pigs.	Some protection will be afforded to rare and listed plant species due to fencing existing populations. However, sustained protection will be difficult due to the ability of pigs to break through fencing. Populations will not be able to recover to new habitats because of the continued presence of feral pigs.	Same as Alternative Two except that it will take approximately 5 more years to achieve the feral pig eradication and protect the rare and listed plants.
Non-Native Plants	Non-native plants will continue to benefit from the ground disturbance activities of feral pigs. Fennel will continue to expand into native plant communities and establish dominance.	Fennel burn may enhance Mediterranean annual grasses. Fennel will be greatly decreased. Herbicide application will greatly reduce fennel and should reduce other non-native dicots. Removal of pig disturbance will substantially reduce long-term establishment and spread of non-native plants.	Environmental consequences will be similar to Alternative One: No Action for the central and western portions of the island. To the extent that pigs can be excluded from the eastern 24% of the island, the environmental consequences will be similar to Alternative Two.	Same as Alternative Two. Fence building and removal will likely create some bare ground and may increase weed spread into disturbed areas near fencelines.
Native Island Fauna	Pigs will continue to directly and indirectly impact native wildlife through destruction of habitat, predation, and competition for food, supporting enhanced populations of predators (such as ravens). Island Foxes will face continued predation from non-native golden eagles.	There will be short-term effects on small animals due to the fennel burn. Elimination of dense fennel stands will cause changes in species composition in the long-term. Herbicide treatment is not expected to affect island fauna. Feral pig eradication will remove direct competition and predation on many island animal species. Island foxes would not face predation from non-native golden eagles nor competition for food.	Same as Alternative One: No Action for Island Foxes. Native wildlife, such as mice, lizards, and snakes on the eastern portion of the island will benefit (similar to Alternative Two) from the eradication of feral pigs in that area.	Same as Alternative Two, although approximately 5 more years will be needed to eradicate the feral pigs.

	Alternative One	Alternative Two	Alternative Three	Alternative Four
Non-native Fauna	Pigs will provide a food supply adequate to support nesting by non-native golden eagles. The golden eagles will also prey on native island endemic species such as the island fox and the island spotted skunk.	Removal of pigs will eliminate the primary prey base for golden eagles. Golden eagles would no longer be able to sustain resident populations on the island.	Effects from fennel burn and herbicide application same as Alternative Two.	Same as Alternative Two, although approximately 5 more years will be needed to eradicate the feral pigs.
Soil and Water	Pig rooting and herbivory will continue to reduce plant cover and greatly increase soil erosion and sedimentation of streams.	Fennel burn and herbicide will reduce ground cover and could lead to increased erosion and stream sedimentation in the short-term. Eradication of feral pigs will greatly reduce soil disturbance, destruction of cryptobiotic crusts, and lessen soil erosion and stream sedimentation. Soil nutrient levels will increase in the short-term from the fennel burn.	To the extent the NPS is successful keeping pigs from reinvading the eastern portion of the island, the environmental consequences in this area will be the same as Alternative Two. However, for the remainder of the island (with the exception of selected fenced areas) the environmental consequences will be the same as Alternative One: No Action.	Same as Alternative Two, although approximately 5 more years will be needed to eradicate the feral pigs.
Cultural Resources	Pigs will continue to destroy irreplaceable archeological sites and will degrade the scientific importance of the Santa Cruz Island Archeological District.	The fennel burn could affect historical resources, such as fencelines. Fire lines in fennel could cause ground disturbance. The primary impactor of archeological sites, feral pigs, would be eliminated in approximately two years.	Most of the Santa Cruz Island Archeological District will continue to be impacted by feral pigs. To the extent that pigs are excluded from the eastern portion of the island, archeological sites in that area will be protected.	Same as Alternative Two, although approximately 5 more years will be needed to eradicate the feral pigs.

	Alternative One	Alternative Two	Alternative Three	Alternative Four
Human Uses	Human uses will be largely unchanged. The aesthetics of visits to Santa Cruz Island will be lessened due to the reduction of native wildlife, reduction of plant cover, and destruction of archeological sites. The scientific value of the island will decrease. Pigs may occasionally be dangerous to people in certain situations.	Elimination of dense stands of fennel will improve the attractiveness of the isthmus for visitor use. Visitor use and access may be limited while hunting of feral pigs is active in selected areas. Elimination of pigs will improve island aesthetics, scientific values, and recreational opportunities.	Environmental effects will be similar to Alternative Two for most recreational uses. The scientific value of most of the island will decrease. Pigs may occasionally be dangerous to people in the central and western portions of the island.	Same as Alternative Two, although approximately 5 more years will be needed to eradicate the feral pigs.

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CHAPTER FIVE

CONSULTATION AND COORDINATION

Coordination

Public Law 96-199, the act that created Channel Islands National Park, allows for federal funds to be used for cooperative resource management on lands owned by The Nature Conservancy within the boundaries of Channel Islands National Park. Cooperative management between the Park and TNC is essential for many resource issues that cannot be contained within ownership boundaries. Such issues include management of weeds, terrestrial resources (especially Santa Cruz Island Fox management), and feral animals.

As discussed in Chapter One, management of the feral pig population on Santa Cruz Island is the top priority for the TNC/NPS cooperative resource management effort. The Park has embraced TNC as a full partner in the development of strategies to eliminate pigs from Santa Cruz Island. Under TNC management, pig control, and research into feral pig impacts have been ongoing for 20 years. This experience has made them uniquely qualified to provide expertise into the development of this project.

As a federal project, the National Park Service retains final decision making authority for this project. As private landowners, TNC is not bound to implement the Park's decision. However, successful implementation of this project is contingent on TNC supporting the Park's decision. To ensure success of the project, the Park will enter into a cooperative agreement with TNC to implement the Park's decision. The agreement will outline the necessary actions each entity must undertake to implement the project.

Public Involvement

Internal Scoping and Public Involvement Process

The NEPA "scoping" process [40CFR 1501.7] was used to determine the scope of the analysis and to identify potential issues and opportunities related to the Proposed Action. A complete summary of the scoping and public involvement process for the proposed project is as follows:

Internal Scoping

The Park has successfully eradicated pigs on Santa Rosa Island. Through this effort the Park has collective knowledge about the issues surrounding pig impacts and pig eradication.

External Scoping

External scoping refers to the effort the Park made to solicit input from the local public, organizations, and other government regulatory agencies. Of particular note is the contribution of knowledge to the Park from The Nature Conservancy. Over 20 years TNC has been involved in pig control efforts on owned lands of Santa Cruz Island. The Park has worked in close cooperation with TNC in developing both pig eradication alternatives as well as fennel control measures. The outreach methods the Park used to solicit input included: scoping letter, public meetings, presentations, website, and direct communications.

Scoping Letter

A letter describing the proposed action was sent to individuals and organizations who expressed interest in the Park's management, and government agencies who might have oversight/regulatory concerns about the project.

Public Meetings

On October 27th in Santa Barbara and on October 20th, 1999 in Ventura the Park hosted public meetings. As part of this meeting the Park presented the need for the proposed action as well as the proposed action.

Presentations

The Park and TNC met with several local organizations and interested agencies to personally inform them of the purpose and need for this action.

Website

The Park posted information regarding the project on its website.

Direct Communication

The Park made direct communication to regulatory government agencies that may have oversight concerns regarding the project. A list of these agencies can be found below.

List of Preparers

DEIS Preparation

Individuals who helped prepare the Draft EIS are as follows:

Steve Ortega	Restoration Specialist	Channel Islands NP
Kate Faulkner	Natural Resources Division Chief	Channel Islands NP
Erik Aschehoug	Land Planner	The Nature Conservancy
Tim Coonan	Branch Chief for Terrestrial Monitoring and Restoration	Channel Islands NP
Sarah Chaney	Restoration Specialist	Channel Islands NP

Dirk Rodriguez	Monitoring Botanist	Channel Islands NP
Ann Huston	Cultural Resources Division Chief	Channel Islands NP

DEIS Review

Allen Schmierer	Environmental Compliance Specialist	Pacific West Region – National Park Service

DEIS Technical Assistance

Cathy Schwemm	GIS Specialist	Channel Islands NP

Notification and Distribution of DEIS

Notification

The Park will widely distribute the Draft EIS for comment. Methods the Park will use in notifying the general public that the DEIS is available for comment include:

Press Release

The Park will issuing a press release to the 50+ local media outlets that are part of the Park's Public Relations mailing list.

Legal Notice

Placement of a legal notice that announces the availability of the Draft EIS for review will be placed in both the Santa Barbara News Press and the Ventura County Star.

Website

The Park will post the DEIS on its website in PDF format. http://www.nps.gov/chis/homepage/restoringsci.html.

List of Recipients

Government

- California Department of Fish & Game
- U.S. Fish and Wildlife Service (Ventura Office)
- Environmental Protection Agency (Washington Office)
- California Environmental Protection Agency
- Central Coast Regional Water Quality Control Board
- California Coastal Commission
- National Marine Fisheries Service
- Channel Islands National Marine Sanctuary
- U.S. Army Corps of Engineers
- U.S. Geological Survey
- U.S. Coast Guard
- Honorable Lois Capps
- Honorable Elton Gallegly

Organizations and Businesses

- Santa Barbara Museum of Natural History
- National Wildlife Research Center
- Institute for Wildlife Studies
- The Nature Conservancy
- Santa Barbara Botanic Garden
- Catalina Island Conservancy
- Environmental Defense Center
- National Parks and Conservation Association

- California Native Plant Society
- National Fish and Wildlife Federation
- Pacific Seabird Group
- Santa Cruz Island Foundation
- Island Packers
- Vail and Vickers

Individuals

- Dr. Larry D. Agenbroad
- Dr. Scott Anderson
- Jeanne Arnold
- Dr. Reg Barrett
- Dr. Michael Benedict
- Timothy K. Boyle
- Cherie Bratt
- Dr. PatriciaBrown
- Harry R.Carter
- Dr. Charles Collins
- Paul W. Collins
- Dr. Scott D. Cooper
- Marla Daily
- Robert L. DeLong
- Diane Devine
- Thomas W. Dibblee, Jr.
- Clive E. Dorman
- Dr. Jenifer Dugan
- Mary Elaine Dunaway
- Jack Engle
- Dr. Wayne R. Ferren
- Amy Fesnock
- Laura J. Furlong
- Dr. Steve Gaines
- Dr. Michael A. Glassow
- Stephen R. Gliessman
- Jay Goldsmith
- Dr. Daniel A. Guthrie
- Peter L. Haaker
- Dr. Sally Holbrook
- John R. Johnson
- Donald Lee Johnson
- Kathy Jope
- Steven A. Junak
- Jon Keeley
- Doug Kennett
- Dr. Kevin Lafferty
- Dr. Lyndal Laughrin
- James Lima
- Dewey Livingston
- Dr. Larry Loeher
- Lynn Lozier
- Dr. Kathryn McEachern
- Dr. Leal A.L. Mertes
- Diane Noda
- Dr. Elizabeth L. Painter
- Ralph Philbrick
- Fred Piltz
- Dr. Elizabeth L. Painter
- Ralph Philbrick
- Fred Piltz
- Jerry Powell
- John Randall
- MarcelRejmanek
- Elizabeth Riddle
- Dr. Gary Roemer
- Gary Rosenlieb
- Dr. M.A. Sanjayan
- Peter Schuyler
- Jim Shevock
- Dr. Robin Throp
- Dr. Dirk Van Vuren
- Dr. Nancy Vivrette
- Dr. Hartmut Walter
- Libe Washburn
- Dr. Adrian M. Wenner
- Dr. Dieter Wilken
- Dave Chipping
- Emilie Roberson
- Jake Sigg
- Dave Tibor
- Connie Rutherford
- Brian Huse

The Park maintains a mailing list of individuals and organizations interested in the activities of Channel Islands National Park. The executive summary and a notice will be sent to this mailing list that notifies them that the DEIS is available for review. The notice will give instructions on how to obtain a copy of the DEIS, view it at the Park's website, or review at the Park or the local library. To reduce costs associated with distribution of paper copies, the

Park will distribute the DEIS on CD-roms. Only upon special request will paper copies be distributed.

Response to Comments

At the public meeting comments were given regarding the project. In addition, the Park received five written comments on the proposal during the scoping period. The comments received on the proposal were either asking the Park to consider a certain alternative, or to consider certain impacts which may occur as a result of implementing the proposed action.

Alternatives

Comments the Park received during the scoping period asked that the Park consider sport hunting as part of the eradication effort. The Park dealt with the issue of Sport Hunting as follows:

Sport Hunting

This alternative was considered but was dismissed from consideration (see Chapter Two, "*Alternatives Dismissed from Further Study"*).

Impacts

The comments the Park received on potential impacts to wildlife species asked that the analysis include impact analysis for the Island fox. This species was addressed in the Native Island Fauna section in Chapter Four.

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